



# **EFFECTS-BASED DECISION MAKING IN THE WAR ON TERROR**

## **GRADUATE RESEARCH PROJECT**

**Major Robert K. Umstead**

**AFIT / GOS / ENS / 05-15**

**DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY**

**AIR FORCE INSTITUTE OF TECHNOLOGY**

**Wright-Patterson Air Force Base, Ohio**

**APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.**

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government.

EFFECTS-BASED DECISION MAKING IN THE WAR ON TERROR  
GRADUATE RESEARCH PROJECT

Presented to the Faculty  
Department of Operational Sciences  
Graduate School of Engineering and Management  
Air Force Institute of Technology  
Air University  
Air Education and Training Command  
In Partial Fulfillment of the Requirements for the  
Degree of Master of Operational Sciences

Robert K. Umstead, B.S., MBA

Major, USAF

June 2005

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

EFFECTS-BASED DECISION MAKING IN THE WAR ON TERROR

Robert K. Umstead, B.S., MBA

Major, USAF

Approved:

// SIGNED //

31 May 2005

---

DAVID DENHARD, Lt Col, USAF

---

Date

## **Abstract**

In recent years, effects-based planning, execution, and assessment has moved from doctrinal debate to operational implementation in the U.S. military. Although effects-based operations (EBO) implementation strategies vary among the combatant commands and services, each faces the difficult task of planning and assessing their operations. United States Pacific Command, the sponsor of this research, faces these challenges on a daily basis as they fight the war on terror in their area of responsibility.

From an operations research (OR) prospective, EBO formulations resemble networks with structures ranging from hierarchical (objective-effect-action-resource chains) to closed (systems-of-systems nodal chains). Many traditional OR network techniques can be employed to analyze these formulations. This project investigates two such techniques; network flows and risk analysis to identify nodes of influence (centers of gravity) and courses of action (sets of actions). Applications of these techniques span the entire spectrum of military operations, but are particularly suited to the war on terrorism.

## Table of Contents

|  | Page |
|--|------|
| Abstract.....  | iv   |
| Table of Contents.....   | v    |
| Executive Summary.....   | vi   |
| Chapter 1. Viewing the Center of Gravity through the Prism of EBO.....   | 1    |
| Chapter 2. A Methodology for Course of Action Development, Evaluation, and Selection for Effects-Based Operations..... | 14   |
| Appendix A. Literature Review of Existing Military Planning Methods.....   | 28   |
| Appendix B. Literature Review of Operations Research Networks for Modeling Terrorist Organizations .....               | 46   |
| Bibliography.....  | 60   |

## **Executive Summary**

The genesis of this project came eighteen months ago in the Nevada desert, in the middle of the night. As is often the case, it began during another project on a related topic. At the time, it made sense that a generic model of a global terrorist organization in the same vein as that for a nation-state would be a much more efficient way of preparing for war. After all, a generic model would make tactics development, training, and mission rehearsal more efficient, right? The project lay dormant until January 2005 when a formal study of terrorist organizations and the US approach to fighting a campaign began. Unfortunately, as in most cases, execution is not as simple as concept generation.

The fundamental issue is not a model of a terrorist organization. Rather, the issue is how the US thinks about, and specifically for this project, prepares for war. Part of the ongoing transformation of the military is an evolution from the current strategy-to-task approach to planning military operations to a system of systems methodology called Effects-Based Operations (EBO).

This transformation is happening at our combatant and service components today. The project's sponsor, United States Pacific Command, requested support to "examine the decision processes employed by the Combatant Commanders and make recommendations for improved effects based decision making in executing the War on Terrorism." Two general areas of study are applicable to the USPACOM request, decision analysis in modern warfare and the implementation of EBO.

To address these areas two literature reviews were initially conducted. The first (Appendix A) reviews the current and proposed methods to plan, execute, and assess military

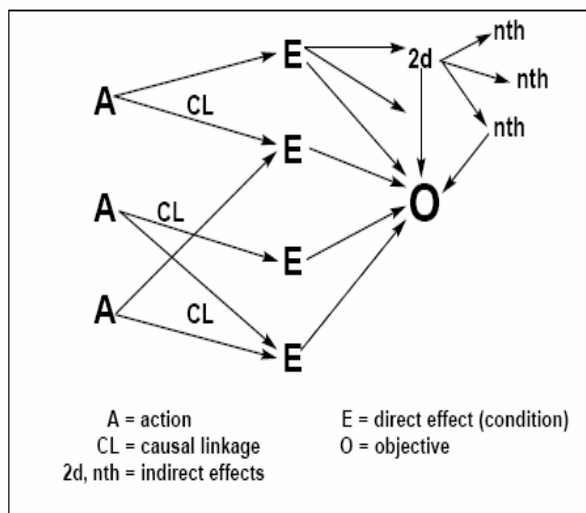
operations. The second (Appendix B) reviews operations research techniques that are available to support the planning, execution and assessment of military operations. While the literature is separated topically, in order to make better decisions in the war on terror the two go hand in hand.

## **Evolution**

Strategy-to-task is an objectives-based planning method currently used by the US Armed Forces. The methodology is effective for both deliberate and crisis action planning, well understood by the user and ties tactical actions to national objectives. EBO is a method to plan, execute, and assess operations based on a system of systems analysis of the adversary's political, military, economic, social, infrastructure, and information systems. The first “actionable” publication in the field of EBO was *Thinking Effects, Effects-Based Methodology for Joint Operations* by Mann, Endersby and Searle (2002). In the paper, the authors illustrated the change from a focus on an objectives-based method to a focus on the linkages between actions, effects and objectives (figures 1 and 2 below).



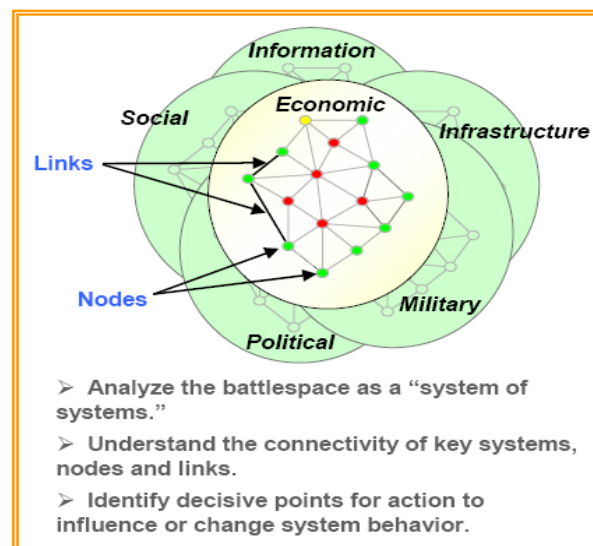
**Figure 1.** Objectives-Based Methodology (Mann et al 2002, 47)



**Figure 2.** Effects-Based Methodology (Mann et al 2002, 49)



With the publication of the Joint Warfighting Center Joint Doctrine Series, Pamphlet 7, *Operational Implications of Effects-Based Operations* in 2004, the formulation moves fully to a system of systems baseline to develop the relationships between effects, nodes, and actions (figure 3).



**Figure 3.** Systems of Systems Model (JWC Pam 7 2004)

## **Moving Forward**

The transformation to EBO is moving rapidly, but several issues between how the military plans today and proposed implementations of EBO need to be reconciled. This project addresses two of those issues.

First, the concept of a center of gravity has been a core part of military planning since Clausewitz. Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms*, currently defines a center of gravity as “those characteristics, capabilities, or sources of power from which a military force derives its freedom of action, physical strength, or will to fight.” Chapter one draws from operations research-based techniques for social network analysis to modify the center of gravity concept to handle the complexities of warfare today by meshing centers of gravity with the EBO system of systems methodology through the concept of

a maximum influence node. The proposed methodology provides planners a means to view the familiar center of gravity concept within the new EBO construct.

Second, Chapter two describes a methodology for developing, evaluating, and selecting courses of action (sets of actions) using techniques from the field of risk analysis. The methodology provides decision makers with courses of action that balance the likelihood of success with risk to friendly forces and the impact on future operations while minimizing the potential for “campaign by target list management.”

Warfare has always been complex. With the additional political, economic, social, and informational challenges of the war on terrorism, the complexity will only increase. Eighteen months later and after six months of formal study in the relative comfort of a classroom, the generic model of a terrorist organization conceived in the Nevada desert is still viable, but the initial emphasis was on the wrong problem. In order to transform the way the Armed Forces think about war, the methods used to plan, execute, and assess operations must adapt to meet the complexity of warfare today. Viewing a center of gravity in terms of influence on a terrorist organization and selecting courses of action using a multi-criteria risk assessment are two methods of accomplishing this transformation.

# **Viewing the Center of Gravity through the Prism of EBO**

Maj Robert Umstead and Lt Col David Denhard

June 2005

Submitted to Joint Force Quarterly

In the May/June 2002 issue of *Foreign Affairs* Defense Secretary Donald Rumsfeld described the strategy for transforming the U.S. military. Part of that strategy is to “change not only the capabilities at our disposal, but also how we think about war.”<sup>1</sup> Fundamentally, joint doctrine describes how the Armed Forces think about war; and under the Secretary’s vision it is changing to meet the 21<sup>st</sup> century challenges of global terrorist organizations as well as nation-states. As a part of this transformation, the battle proven objectives-based methods used to plan, execute and assess operations are evolving to Effects-Based Operations (EBO). But how radical should this evolution be? More specifically, how will the traditional, hierarchal focus on a center of gravity (COG) evolve into a connection of actions, effects, and objectives to achieve an end-state?

In recent years, effects-based planning and assessment has moved from doctrinal debate to operational implementation in the U.S. military. Although EBO implementation strategies vary among the combatant commands and services, each faces the difficult task of planning and assessing their operations. US Joint Forces Command’s Joint Warfighting Center Joint Doctrine Series Pamphlet 7 provides valuable insight in implementing EBO. The pamphlet defines EBO, discusses in detail an effects-based approach to planning, execution and assessment, and reviews operational implications to doctrine, leadership and education, and training. A frame of reference showing how the existing objective-based planning concepts (Joint Pub 3.0 *Doctrine for Joint Operations*, Joint Pub 5-00.1 *Doctrine for Campaign Planning*) are folded into the EBO design would be beneficial for current planners learning how to implement EBO. To that end, the authors illustrate a means for viewing COGs through the prism of EBO.

The definition of “EBO” has evolved as the concept of EBO has developed. For many, the definition of EBO has been a moving target. For this article, the authors use the EBO

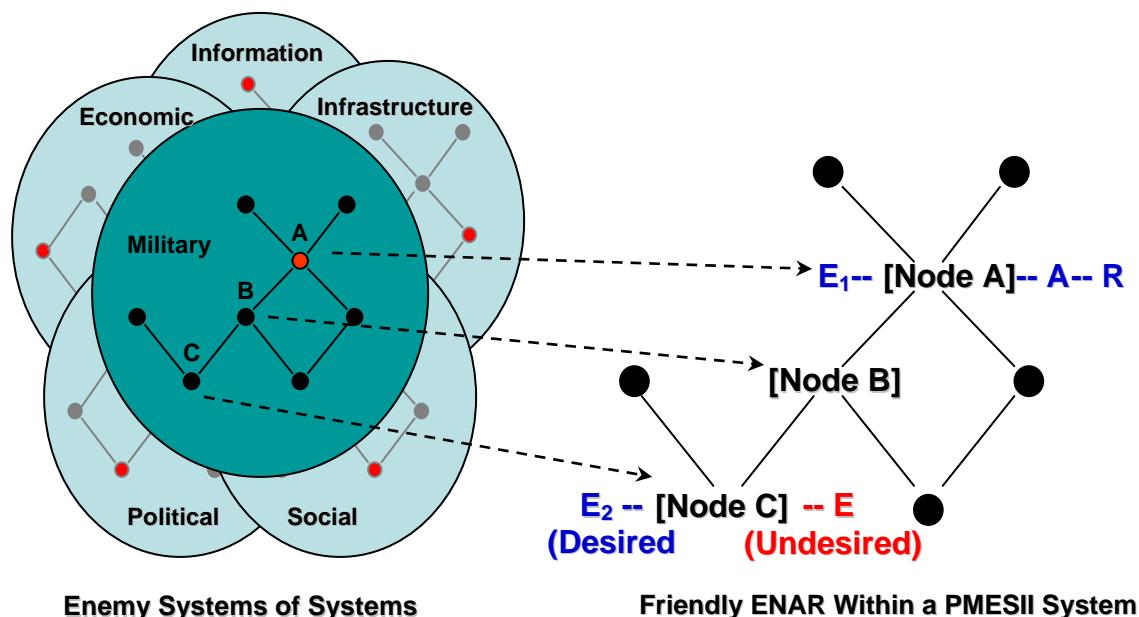
definition in Pamphlet 7: “Operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims.”<sup>2</sup>

### **EBO Today**

With the publication of Pamphlet 7 in 2004, the effects-based methodology has fully evolved from a linear strategy-to-task approach to a system of systems baseline to develop relationships (or linkages) between effects, nodes, and actions. The three key EBO components (planning, execution, and assessment) are enabled by a collaborative information environment and operational net assessment. Operational net assessment is intended to provide a holistic understanding of the environment through a system of systems analysis or SoSA (figure 1). Within each of the six interrelated political, military, economic, social, infrastructure, and information (PMESII) systems, “nodes” represent a functional component of the system (person, place, or thing) and “links” represent the relationships (behavioral, physical, or functional) between the nodes.<sup>3</sup>

In the effects-based planning method described in the pamphlet, an adversary SoSA output determines the direct and indirect relationships between nodes across the PMESII that can be exploited by friendly actions. SoSA results become the input for the development of a linkage between enemy nodes and friendly Effects, Nodes, Actions, and Resources or ENAR (figure 1). Understanding these relationships allows commanders to choose from a set of ENAR options when developing and selecting courses of action. In figure 1, direct relationships exist between adjacent nodes A and B as well as between nodes B and C. Indirect relationships exist between nodes related through another node, in this case between nodes A and C. The ENAR construct

also represents desired as well as undesired effects. In pamphlet 7, desired effects are those that support the strategic objectives while undesired effects could have an adverse impact on the strategic objectives. An undesired effect is shown at node C because of an action at node A.



**Figure 1. Systems of Systems Model (JWC Pam 7 2004)**

Notably, this effects-based planning description does not use the term “center of gravity.” The intent of SoSA is to treat each PMESII element as a system and the entire PMESII structure as a system of systems. The product is a nodal analysis that forms the basis for coupling nodes to effects, actions and resources. This SoSA approach, as described in the pamphlet, does not employ the traditional center of gravity analysis outlined in joint doctrine.

Does changing the way the DoD thinks about war mean the seemingly timeless concept of the center of gravity has run its course? Alternatively, does changing the way the military thinks about war mean adapting the center of gravity concept to handle the complexities of warfare today?

### **COGs through an EBO Prism**

The authors of Pamphlet 7 identify the need to redefine “center of gravity” in broader terms if EBO is adopted. One approach to a broader definition of a COG is provided by Strange and Iron. COGs are defined as “dynamic and powerful physical and moral agents of action or influence with certain qualities and capabilities.”<sup>4</sup> In the SoSA methodology, Strange and Iron’s definition can be applied to nodes with influence over other nodes in the system. The level of influence of a node would be driven by the “qualities and capabilities” of that node. Further, Echevarria argues center of gravity could be redefined to mean “focal point.”<sup>5</sup> This definition also lends itself to a nodal structure. The SoSA approach in pamphlet 7, strictly speaking, does not require a center of gravity to be effective. Therefore, another option is to adopt this network-based method and eliminate center of gravity from joint doctrine.

However, as a practical matter, it is unlikely planning staffs around the world would embrace a new methodology that does not address COGs, at least not in the short term. The issue then becomes what additional advantages does a SoSA offer and what is the best way to view the concept of a center of gravity in this new network construct.

The current COG methodology is a hierarchal approach based on Strange’s 1996 definition of center of gravity.<sup>6</sup> Capabilities, requirements, and vulnerabilities are arranged in a tree structure where nodes branch out from a center of gravity (see figure 2a). This approach is very effective at capturing the direct relationships between vulnerabilities and a COG. It is not effective at capturing the indirect relationships between two or more requirements of a given COG or between multiple COGs. The tree structure of this approach cannot account for the added complexity involved with these indirect relationships. A network approach, figure 2b, is

flexible enough to “map causal relationships between components of the system” as demonstrated by Henderson<sup>7</sup>. In this network structure, capabilities, requirements, and other qualities define the influence of each node. The node with the greatest influence becomes the COG. Each node and link is potentially vulnerable. Visualizing the causal relationships between components of an adversary network is one overriding advantage of a SoSA.

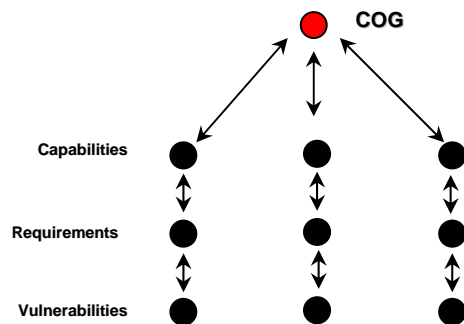


Figure 2A: COG

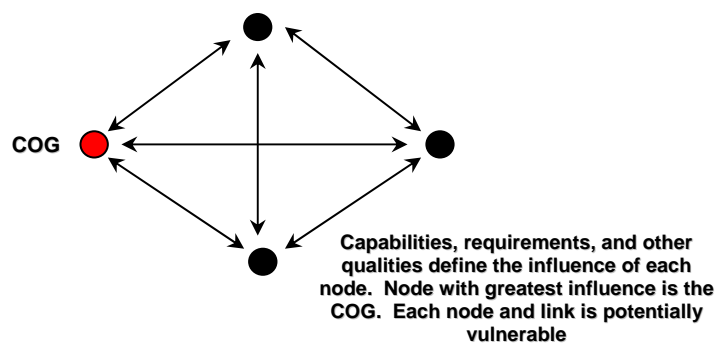


Figure 2B: Network Structure Applied to a COG

Fortunately, evolving from a hierarchal to a network structure to represent an adversary system does not mean we lose the fidelity currently available. Referring again to figures 2a and 2b, the hierarchal linkages in the current COG model can be retained in the SoSA model while the indirect relationships can now be explicitly modeled. Additionally, as well as retaining the information available through current COG analysis, a SoSA can produce a descriptive model of the relationships between the components of the six PMESII systems not captured by current COG modeling methods. Changing the way the DoD thinks about war will not require concluding Clausewitz was wrong, the concept of the center of gravity is as timeless as ever. However, adapting the center of gravity concept to handle the complexities of warfare today is necessary, and a SoSA approach will allow for this.



### **Adapting to the Complexity**

To further adapt the center of gravity to the SoSA network as presented in Pamphlet 7, the authors introduce the concept of maximum influence of a node within a network. To facilitate this concept, the Pamphlet 7 definition of a node “a person, place, or thing,” is extended to include an “event.” For example, in Iran Hashemi Rafsanjani, Doshan Tapeh Air Base, nuclear weapons, and Ramadan are all potential nodes. Additionally, the authors also extend the Pamphlet 7 definition of an action from “an activity directed at a specific node” to “an activity directed at a specific node or link.” A maximum influence node is consistent with the previously discussed broader definition of a COG from Strange and Iron.<sup>8</sup> Further, Renfro and Deckro observe two key characteristics of a maximum influence node.

First, the node with the maximum influence is a pressure point. Second, the best way to influence (or act on) this pressure point may not be through a direct attack but rather through other nodes within the system.<sup>9</sup> Since influence and power are synonymous, the node with maximum influence within a given system is the most powerful node. This is also consistent with Echevarria’s “focal point” definition<sup>10</sup>. A product of the systems analysis; the authors use the node with maximum influence as the center of gravity of a PMESII element.

A maximum of six nodes could represent the COGs of the PMESII system, one COG for each system. On the other hand, if the most influential node in the political system is also the most influential node in the social system, then these two PMESII systems will share the same center of gravity. Insight is gained into the relationships between system components in either case.

Returning to the SoSA illustration in figure 1, the concept of meshing COGs into an effects-based methodology is illustrated for a PMESII network. For simplicity, the network structure is limited. In figure 1, the red nodes represent the most influential nodes in the network and are the centers of gravity. With COGs included, the development of a linkage between effects, nodes, actions, and resources or ENAR still follows directly from the SoSA results as described in Pamphlet 7.

ENAR is similar to listing the capabilities, requirements, and vulnerabilities in order to develop courses of action, but provides the commander with a wider array of options to achieve the desired outcome through a broader understanding of the adversary. Recognizing a link may be a more lucrative (or vulnerable) target than a node in terms of influence on the system, we add the link into the construct so ENAR becomes effect, link, node, action, resources or ELNAR. Figure 3 combines the center of gravity and the linkage between effects, nodes, links, actions, and resources.

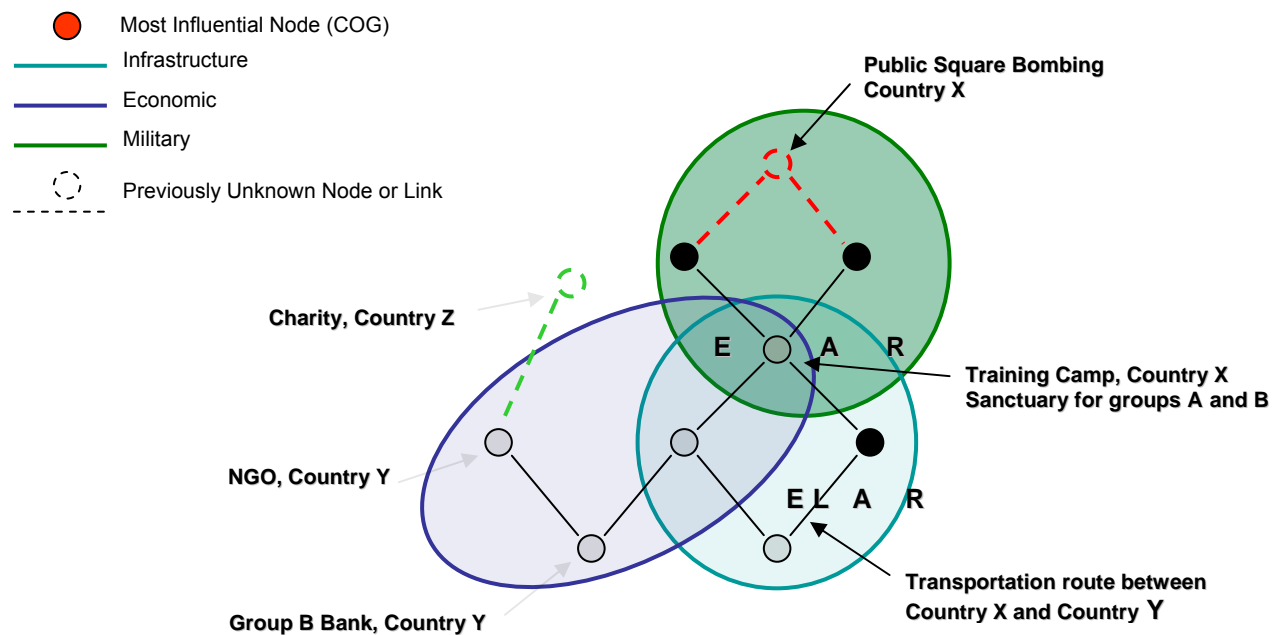


Figure 3: Regional Terrorist Group Example

Figure 3 shows three systems (military, infrastructure, and economic) of a simplified PMESII network with the most influential node (or COG) in each system being the same node (shown in red). Effects, actions and resources are linked to one node and one link. Secondary or indirect effects (desired in blue and undesired in green) are shown manifesting themselves through previously unknown nodes and linkages.

To illustrate in a more concrete manner we will use two notional examples, one of a regional terrorist group and the other a more conventional air defense system. Our notional terrorist group, group A, has a presence in countries Orange and Black. Group B is a local ally in country Black where it receives support from a non-governmental organization and provides support to group A in the form of funding and fighters.

The maximum influence node, or center of gravity, is a training camp where both notional groups have sanctuary and reside at the same time. That is, the military, economic, and infrastructure elements of each group overlap at this node. Two of the notional desired effects are disrupt the operation of the group A and kill or capture members of groups A and B. To that end effects, actions and resources are matched to the center of gravity and to a transportation link between countries Orange and Black. In other words, we attack group A directly at the center of gravity and indirectly through the maritime transportation link. In this case, friendly actions have a desired effect of the discovery of a charity acting as a funding source and the undesired effect of a public square bombing by a previously unknown cell or individual. While applicable to a terrorist organization, this SoSA methodology still applies in our more conventional example of an air defense system.



of maximum influence as a center of gravity. An important caution is necessary at this point. EBO is not a cookie cutter approach. COGs are a product of a SoSA, not the other way around. Additionally, COGs produced through a disciplined SoSA process may not be what some planners would consider the “traditional” centers of gravity. For example, “leadership” is more often than not a default COG. However, Marion and Uhl-Bien, through a network analysis of Al Qaeda, demonstrate the direct influence of the core leadership over the network may be in fact limited<sup>11</sup>. Finally, there are some important limitations to planning with the SoSA network.

### **Limitations**

One practical limitation of the SoSA approach in pamphlet 7 is the size of the PMESII network itself. As we have seen with the previous examples, the system of systems analysis was significantly simplified yet the PMESII network appears relatively complex. An actual PMESII network, depending on how they are constructed, could have hundreds of nodes for each PMESII element. In a quest to gain “total battlespace awareness”, the planning staff could induce self-paralysis by having too many nodes. Another problem will be the availability of data to populate the network. If the intelligence does not exist to describe the nodes and links within a PMESII element, the network may not be sufficient to select or even identify a COG. To be sure, perfect information is impossible to obtain. Hence, a complete and perfect understanding of the battlespace is not realistic. What are realistic are a descriptive model of the adversary and an improved understanding of the relationships, or linkages, between components of the adversary system. Neither of these expectations is possible with a COG focused objectives-based approach. Knowing how many nodes and how much information is enough to conduct campaign planning will be part of the operational art of the 21<sup>st</sup> century.

### **Moving Forward – Slowing Down the Prism**

The evolution of EBO will continue to accelerate as the doctrine develops. Changing the way the military thinks about war means modifying the center of gravity concept to handle the complexities of warfare today. One method of accomplishing this adaptation is to mesh centers of gravity with the SoSA methodology through the concept of a maximum influence node. This enables planners to see centers of gravity through an EBO prism, and completes at least a portion of the transformation from the hierarchical strategy to task approach of the Cold War to the network structure of Effects Based Operations in the 21<sup>st</sup> century.

### **Notes**

1. Donald H. Rumsfeld, "Transforming the Military," *Foreign Affairs* vol. 81, no. 3 (May/June 2002), pp. 20-32
2. Joint Warfighting Center Joint Doctrine Series Pamphlet 7, *Operational Implications of Effects-Based Operations*. US Joint Forces Command. 17 November 2004, p.2
3. Ibid, p. 10
4. Joseph L. Strange and Richard Iron, "Center of Gravity, What Clausewitz Really Meant," *Joint Force Quarterly*, issue thirty-five, April 2005, pp. 20-27
5. Antulio J. Echevarria II, "Center of Gravity, Recommendations for Joint Doctrine," *Joint Force Quarterly*, issue thirty-five, April 2005, pp.10-17
6. Joseph L. Strange, *Centers of Gravity & Critical Vulnerabilities: Building on the Clausewitzian Foundation So That We Can All Speak the Same Language*, Perspectives on Warfighting Series, no. 4, 2d ed. (Quantico, Va: Marine Corps Association, 1996)
7. Darrall Henderson, *Modeling a Strategy for the War on Terrorism*, US Army War College, Carlisle Barracks, Pennsylvania, 2002, pp. 6-9
8. Joseph L. Strange and Richard Iron, "Center of Gravity, What Clausewitz Really Meant"
9. Robert S. Renfro and Richard F Deckro, "A Flow Model Social Network Analysis of the Iranian Government," *Military Operations Research V8 N1*: 2003, pp 5-15

10. Antulio J. Echevarria II, "Center of Gravity, Recommendations for Joint Doctrine"
11. Russ Marion and Mary Uhl-Bien, "Complexity Theory and Al-Qaeda: Examining Complex Leadership," presented at Managing the Complex IV: A Conference on Complex Systems and the Management of Organizations, Ft Meyers, FL, December 2002, pp. 20

# **A Methodology for Course of Action Development, Evaluation, and Selection for Effects-Based Operations**

Maj Robert “Dagwood” Umstead and Lt Col David Denhard

June 2005



In recent years, effects-based planning and assessment has moved from doctrinal debate to operational implementation in the U.S. military. Although EBO implementation strategies vary among the combatant commands and services, each faces the difficult task of planning and assessing their operations. US Joint Forces Command's Joint Warfighting Center Joint Doctrine Series Pamphlet 7 provides valuable insight in implementing EBO. The pamphlet defines EBO, discusses in detail an effects-based approach to planning, execution and assessment, and reviews operational implications to doctrine, leadership and education, and training. While Pamphlet 7 illustrates how a multitude of actions may be available to accomplish the same result, it does not address *how to decide which actions to take*.

The current objectives-based method detailed in our joint military doctrine uses course of action development, evaluation and selection to determine how a campaign plan will be executed. The result is a set of tactical tasks that are then assigned to units. However, experience has shown that this approach can lead to what has been characterized as “campaign by target list management,” shifting the focus away from obtaining strategic objectives to completing a list of tactical tasks. The same problem can occur with effects-based operations. A list of actions will be developed to achieve the desired effects, but if the default becomes “complete all the actions,” then execution will converge back to “campaign by target list management.” This paper will describe a method for adapting course of action development, evaluation, and selection to EBO by combining effects based planning with techniques from the field of risk management while minimizing the temptation to manage the campaign by “completing all the actions.”

The reader should keep in mind that the definition of “EBO” has evolved as the concept of EBO has developed. For many, the definition of EBO has been a moving target. For this

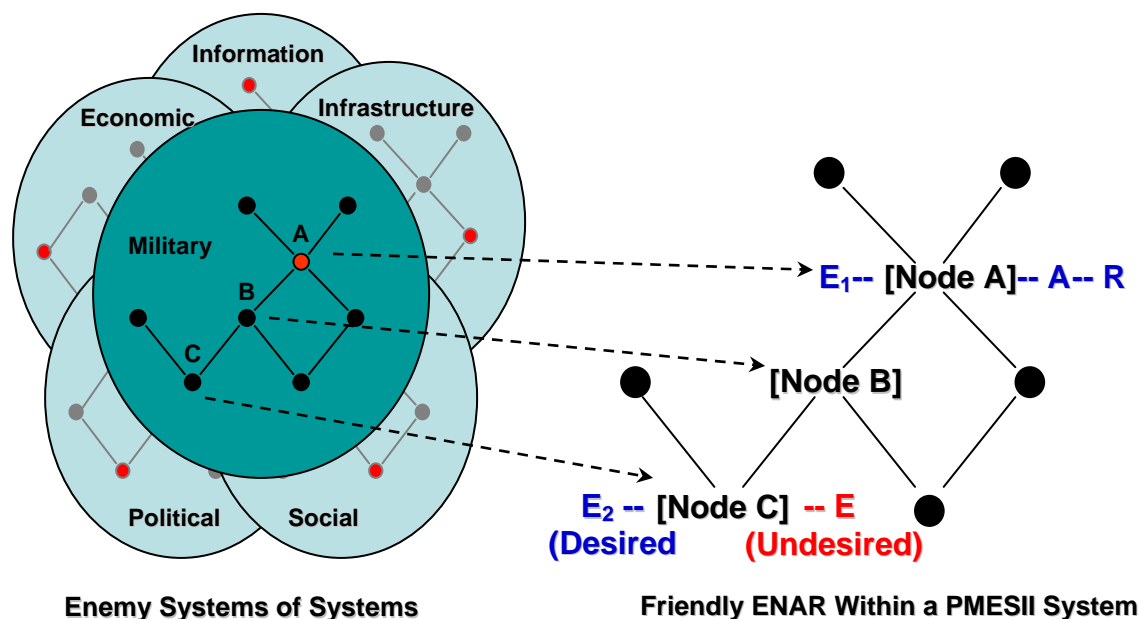
article, the authors use the EBO definition in Pamphlet 7: “Operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims.”<sup>1</sup>

### **EBO Today**

With the publication of Pamphlet 7 in 2004, the effects-based methodology has fully evolved from a linear strategy-to-task approach to a system of systems baseline to develop relationships (or linkages) between effects, nodes, and actions. The three key EBO components (planning, execution, and assessment) are enabled by a collaborative information environment and operational net assessment. Operational net assessment is intended to provide a holistic understanding of the environment through a system of systems analysis or SoSA (figure 1). Within each of the six interrelated political, military, economic, social, infrastructure, and information (PMESII) systems, “nodes” represent a functional component of the system (person, place, or thing) and “links” represent the relationships (behavioral, physical, or functional) between the nodes.<sup>2</sup>

In the effects-based planning method described in the pamphlet, an adversary SoSA output determines the direct and indirect linkages across the PMESII that can be exploited by friendly actions. SoSA results become the input for the development of a linkage between enemy nodes and friendly Effects, Nodes, Actions, and Resources or ENAR (figure 1). Understanding these relationships allows commanders to choose from a set of ENAR options. In figure 1, direct relationships exist between adjacent nodes A and B as well as between nodes B and C. Indirect relationships exist between nodes related through another node, in this case between nodes A and C. The ENAR construct also represents desired as well as undesired effects. In pamphlet 7,

desired effects are those that support the strategic objectives while undesired effects could have an adverse impact on the strategic objectives. An undesired effect is shown at node C because of an action at node A. While the concept is relatively straight forward, the number of possible actions will grow very rapidly when all of the Diplomatic, Informational, Military, and Economic (DIME) instruments of power are considered. The primary driver will be the number of nodes in the PMESII system since each node has generally a minimum of four possible actions. A secondary driver will be the number of possible military, diplomatic, economic and informational actions available to influence a single node.



**Figure 1. Systems of Systems Model (JWC Pam 7 2004)**

With just a few nodes, the number of options grows quickly. For example, with four nodes and four actions (one for each DIME instrument) for each node there would be sixteen possible actions (figure 2). Taken four at a time, the number of possible combinations is 1,820! If the number of nodes in the PMESII is 100, the problem of selecting which actions to take will quickly become unmanageable.

As is becoming evident, the EBO framework provides commanders with the capability to choose individual actions to form a tailored course of action (set of actions) but with the additional cost of having to screen hundreds, maybe thousands, of possible choices. The challenge now becomes determining which core actions contribute the most to achieving the operation's objectives.

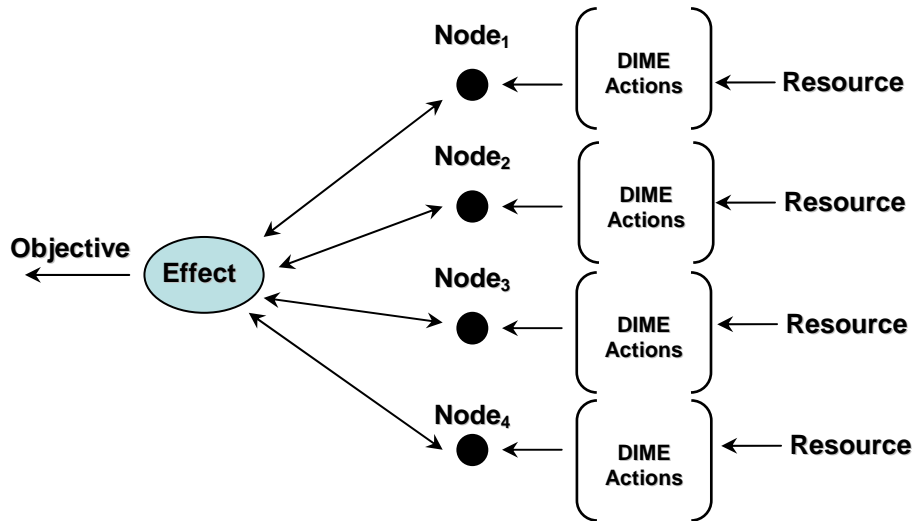
### **From COA themes to sets of actions**

The authors now formally define a course of action as a set of action – resource (AR) linkages selected to achieve the desired effects developed in the planning phase. This definition is consistent with the current doctrinal definition of a course of action as; “the scheme adopted to accomplish a job or mission” or “a possible plan open to an individual or commander that would accomplish or is related to the accomplishment of the mission,<sup>3</sup>” but is more applicable to the EBO construct.

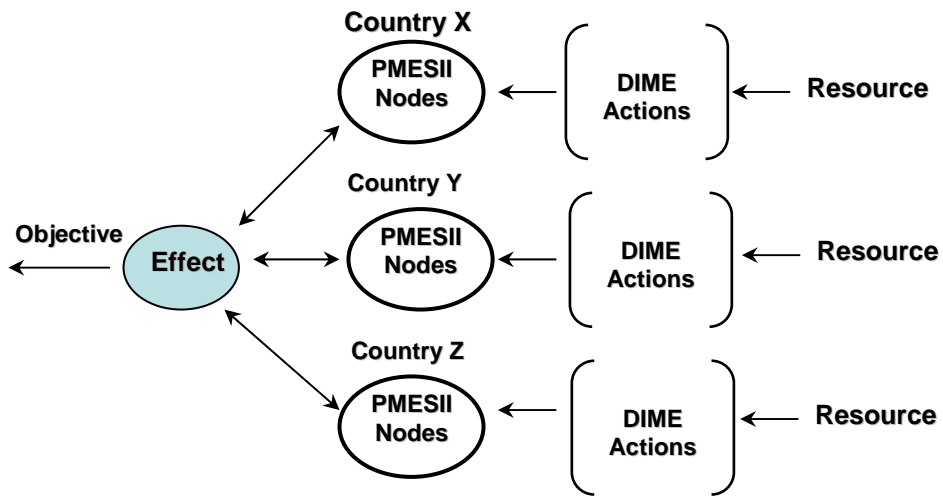
It is important to note that it is necessary to complete the SoSA and ENAR linkages discussed in pamphlet 7 before beginning to develop and select COAs. Currently planners generally develop a COA theme and then develop tasks to go with that theme. Conversely, the EBO method does the reverse. Actions are first developed to achieve the desired result, matched with resources, and then packaged into a course of action. In decision analysis terms, the SoSA and ENAR processes produce the “structure” for the COA decision. Using the ENAR linkages, the result is a much larger and potentially flexible number of COAs than the proverbial “air COA”, “ground COA”, or “mix of both.”

For an operational commander, the ENAR linkages may be viewed on an Area of Responsibility (AOR) basis or on a country-by-country basis. For example, if a desired effect is

terrorist organizations unable to train due to lack of sanctuary, the DIME action(s) taken to achieve this effect may differ between country Z and country Y (figures 2 and 3).



**Figure 2: ENAR on an AOR Basis**



**Figure 3: ENAR on a Country-by-Country Basis**

The current effects-based planning processes provide the structure to develop COAs, but additional aids are needed for COA evaluation and selection. A new approach is introduced to reduce the number of ENAR possibilities to a manageable level and aid in COA evaluation and selection.

This approach is based on the risk filtering, ranking, and management (RFRM) methodology presented by Yacov Haimes in his book *Risk Modeling, Assessment, and Management*<sup>4</sup>. Risk is typically evaluated from the standpoint of identifying “what can go wrong” scenarios along with the scenarios’ associated likelihoods and consequences. This process, combined with a ranking of critical elements, generates mitigation options and assists decision-makers to focus on the largest contributors to risk. Filtering and ranking can also be used to assist military planners in the development and selection of COAs. The methodology would enable planners and leaders to focus on the set of actions that will potentially provide the greatest impact on desired effects and objectives at the lowest possible risk to friendly forces.

The RFRM framework is based on three guiding principles outlined by Haimes<sup>5</sup>. First, due to time and resource constraints, it is often impractical to apply quantitative methods to hundreds of sources of risk. In such cases, qualitative methods may be adequate. In the application to EBO, the number of potential ENAR options is extremely high as previously demonstrated. An initial qualitative step to narrow the options will help focus the decision-making effort.

Second, all sources of evidence such as professional experience, expert knowledge, statistical data, and common sense should be harnessed to assess the significance of the risk sources. In the EBO methodology all of these “sources of evidence” will be important in the evaluation and selection of a set of actions to achieve the desired effects of a given operation or campaign.

The third guiding principle is a set of six questions that combine risk assessment with risk management. To develop and select COAs from an effects-based plan, the authors reduce this to four questions: What ENAR linkages are supportable with resources? What is the likelihood a

given set of ENAR linkages will accomplish the desired effects? What are the consequences of executing a given set of ENAR linkages to our force? What impact will current decisions have on future options? To answer these questions, the COA development, evaluation, and selection process based on the RFRM methodology takes place in six steps.

### **Course of Action Development – Turning ENAR Linkages into COAs**

*What ENAR linkages are supportable with resources?*

In theory, the ENAR linkages have already accounted for the available resources. In reality, the ENAR linkage may define the resources required to accomplish an action, but not necessarily, what resources are in fact available. For this reason, the first step is to filter initially based on available resources. If the resources are not available, eliminate the DIME actions not supported. The result is a large set of supportable ENAR linkages.

*What is the likelihood a given set of ENAR linkages will accomplish the desired effects?*

To answer this question, two steps are required. First, filter again based on phasing and scope. For example, if the desired effects are “no enemy aircraft threaten friendly freedom of maneuver” and “no adversary theater ballistic missile launches”, ENAR linkages that support stability operations do not apply to the situation and can be eliminated (these linkages will be reviewed again in a later step). Further, if the operation is taking place in Country X, ENAR linkages that apply to Country Y are also eliminated. The result of this filtering is a smaller number of ENAR linkages that support the desired effects by phase and scope.

This smaller number is then grouped into *sets of ENAR linkages* based on subject matter expertise and professional experience. Each set of ENAR linkages becomes a candidate course of action.

## **Course of Action Evaluation – Success, Risk, and Priorities**

The next step is to apply quantitative methods combined with commander's guidance, subject matter expertise and professional experience to evaluate the candidate COAs. Varieties of methods are available to quantify the likelihood of success of a given COA. Among these, although not an exhaustive list, are dynamic Bayesian networks, influence nets combined with colored Petri nets, the Analytic Network Process, and influence diagrams.

Ultimately the answer to the question “What set of actions is most likely to accomplish the desired effects?” is not an absolute. There will be too many uncertainties involved. Instead, the result of this step is a ranked set of COAs based on commander's guidance, subject matter expertise, experience, and supported by analysis.

*What are the consequences of executing a given set of ENAR linkages to our force?*

This step is similar to the “risk to forces” and “risk to mission” evaluations currently used. This multi-criterion assessment is based on the priority of the effects achieved by a given COA and the risk to friendly forces of that COA (see table 1). Initially, the ranked COAs from the previous step are distributed into the table based on subject matter expertise and professional judgment. The COA ranked most likely to succeed will not necessarily end up in the “low risk, high priority” section of the table.

COAs in the upper right of the table represent a set of ENAR linkages that have an impact on a high priority effect but also pose a high to extreme risk to friendly forces.



| <div> <div>Effects<br/>Priority</div> <div>Risk To<br/>Forces</div> </div> | Low                     | Medium                  | High                                |
|--|-------------------------|-------------------------|-------------------------------------|
| Extreme  |                         |                         | High to Extreme Risk, High Priority |
| High   |                         |                         | COA 2 ( $P_s \leq .2$ )             |
| Medium   | COA 1 ( $P_s \leq .7$ ) |                         | COA 4 ( $P_s \leq .4$ )             |
| Low  | Low to Negligible Risk  | COA 3 ( $P_s \leq .5$ ) |                                     |
| Negligible   |                         |                         |                                     |

Table 1. Risk-Priority Matrix ( $P_s$  = probability of success)

For this paper, the definitions of risk in the left hand column of table 1 are adopted from Kelly<sup>6</sup>.

*Negligible*: No losses acceptable except those completely unpredictable and unpreventable.

*Low*: Losses only at that expected for normal training or peacetime attrition rates. Accept only favorable engagements.

*Medium*: Losses expected at historical combat rates. Accept neutral or disadvantageous engagements; withdraw to preserve forces.

*High*: Expected losses may render unit unfit for further combat. Accept major losses to achieve objective; Preserve some future capability if able.

*Extreme*: Losses may result in force annihilation. Accept losses necessary to accomplish mission.

The result of this table is a visual representation of the COAs under consideration that combines the likelihood of success, risk to forces, and the impact on high priority effects. Planners can maintain or eliminate COAs based on any combination of these factors combined with commander's guidance.

*What impact will current decisions have on future options?*

Since a COA, once executed, will influence the PMESII network, eliminated ENAR linkages should be reviewed in an attempt to evaluate unanticipated problems in either time or

scope. In this manner, ENAR linkages can potentially be managed to achieve a balance between the various phases of a campaign. For example, while a kinetic attack on a dual use power station may achieve the desired effect of cutting the adversary's communications today, it may also increase the risk to friendly forces later when the power station is being rebuilt during stability operations. This is an example of an undesired effect. To mitigate the increased risk (impact of the undesired effect) later, a different set of actions and resources might be developed for stability operations to account for the damaged power station or, the adversary's communications may be attacked through another node today.

The result of this step is 2-3 courses of action that have a high likelihood of achieving the desired effects, an acceptable level of risk to friendly forces, and an acceptable impact on future operations. The final selection of the course of action to pursue is made by the decision-maker.

### **Deliberate vs. crisis action**

The process of filtering, ranking, and evaluating ENAR linkages to develop, evaluate, and select a COA applies to both deliberate and crisis action planning. In deliberate planning there is generally time to take both a quantitative and qualitative approach to determining the likelihood of success as well as the impact on future options of a given COA. On the other hand, in crisis action planning time constraints are significant. In this case, the quantitative steps could be eliminated from the ranking of candidate COAs; the likelihood of success will be based entirely on professional judgment and subject matter expertise.

### **Limitations**

No single methodology or tool can fit all cases and circumstances. The quantitative methods needed to analyze the likelihood of success of a COA rely heavily on data to populate the PMESII network. Perfect information will not be available. Further, the number of nodes in

the PMESII network will have a significant impact on the methodology. Even after matching resources and filtering based on time and scope, the number of possible ENAR linkages available may still be too high to assess each possible combination. Finally, the ENAR linkages available to planners will likely not be collectively exhaustive given the lack of perfect information about the system. In other words, options may be available the planner is not aware of.

In the end, however, the goal of this filtering and ranking approach is to provide an aid to decision makers, not to make the decisions for them. To improve decision aids for EBO, several areas are available for further research.

### **Areas for Further Research**

What methods are appropriate to represent the impact of actions on the PMESII network? In terms of evaluating the likelihood that a set of actions will produce the desired effects, is it preferable to use a dynamic Bayesian network (DBN), a social network analysis, an influence diagram, or a Markov decision process, etc? Since there are six sub-systems in the PMESII structure, should a different method be used for each sub-system? Finally, is a complex adaptive system preferable given the potential level of complexity and uncertainty involved?

While having a methodology in mind for evaluating the likelihood of success is valuable, the problem of the number of nodes (and the resulting complexity) remains. The DBN approach will decompose the joint probability space using a junction tree<sup>7</sup>. However, a proponent of a complex adaptive system approach will say decomposition is “reductionist,” linear and therefore not a valid approach to what is a complex, non-linear problem. Is the decomposition used in a DBN in fact not applicable?

However, if a fully developed PMESII network is used, the problem will simply be too complex to avoid decomposition in some form. Therefore, what methods can be employed to reduce the number of nodes to a manageable level while maintaining the fidelity of the complex, non-linear relationships in the system of systems approach?

Finally, in addition to evaluating the “risk to forces and risk to mission” discussed earlier, a similar assessment of adversary actions is also made during planning. Typically, this takes the form of “most likely, most dangerous.” In other words, what will the adversary most likely do and what is the most dangerous (dangerous to friendly forces) action or actions the adversary could take? The EBO methodologies currently available do not yet address this aspect of operational level planning and decision aids are not yet available. A risk oriented approach similar to the one described in this paper may be applicable to evaluating adversary actions against friendly forces.

## **Conclusion**

A risk analysis approach to developing and selecting courses of action from an effects-based plan provides decision makers with COAs that balance the likelihood of success with risk to friendly forces and the impact on future operations. The methodology enables a shift in focus from COA themes to tailored COAs focused on desired effects and provides a bridge between effects-based planning and executable options.

## **Notes**

1. Joint Warfighting Center Joint Doctrine Series Pamphlet 7, *Operational Implications of Effects-Based Operations*. US Joint Forces Command. 17 November 2004, p.2
2. Ibid, p. 10

3. Joint Publication 1-02. *Department of Defense Dictionary of Military and Associated Terms*. 12 April 2001 (as amended through 30 November 2004).
4. Yacov Y. Haimes. 2004. *Risk Modeling, Assessment and Management, second edition*. Hoboken: John Wiley and Sons, Inc.
5. Ibid, p. 279
6. Mark Kelly, "Acceptable Risk Level: Just Give Me Guidance and I'll Give You Tactics," *USAF Weapons Review*, Summer 2000, pp. 45-50
7. Uffe Kjaerulff. "dHugin: A Computational System for Dynamic Time-Sliced Bayesian Networks." *International Journal of Forecasting* 11 (1995). pp. 89-111

## **APPENDIX A**

### **LITERATURE REVIEW OF EXISTING MILITARY PLANNING METHODS**

**March 2005**

## Introduction

The transformation the US military is undergoing has led to a great deal of activity in many areas including what hardware the military acquires, how the military trains its personnel, and how the military conducts operations. This paper is a review of current literature regarding the objectives-based methodology currently employed by the military to plan, execute, and assess operations and the effects-based methodology proposed to replace it.

### **Strategy-to-Task Overview (The Current Approach)**

Strategy-to-task is an objectives-based planning and assessment method used today by the US Armed Forces for planning operations (figure 1).

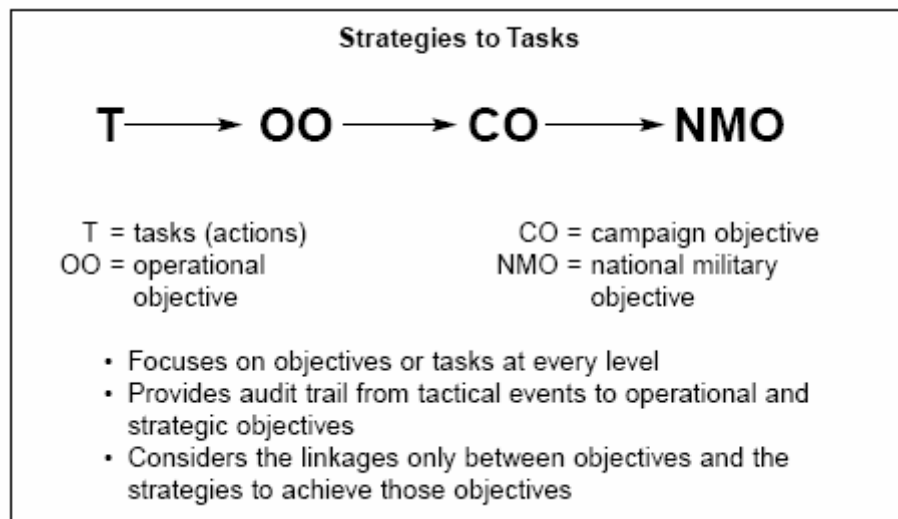


Figure 1. Objectives-Based Methodology (Mann 2002, 47)

The primary strengths of the strategy-to-task approach are:

- Battle Proven
- Well known and understood by the services
- Effective in both deliberate and crisis action planning
- Ties tactical actions to NCA objectives

- Provides flexibility to the JFC during execution

Potential weaknesses of this approach when applied to terrorist organizations are:

- Only addresses direct relationships within the adversary system
- Does not address the causal relationships between components of the adversary system

(Henderson 2002, 9)

- Does not explain why the tasks will lead to the desired objectives (Mann 2002, 47)

Joint Publication 1, *Joint Warfare of the Armed Forces of the United States*, 14

November 2000 is the basis for all US joint doctrine. The current volume ties joint doctrine, together with national security strategy, and national military strategy. This publication defines the instruments of national power as “diplomatic, informational, military, and economic.” Also of interest here are Joint Publications 5-0, 5-00.1 and 3-0.

### **Joint Publication 5-0, *Doctrine for Planning Joint Operations*, 13 Apr 1995**

Joint Publication 5-0 addresses in broad terms planning for the employment of military forces to attain strategic and operational level objectives. It describes the necessity of an interoperable planning system within the military for effective operations. The vehicle for this is the Joint Operation Planning and Execution System. There are three types of planning, campaign, deliberate, and crisis action.

Deliberate planning is normally conducted in peacetime whereas crisis action planning is done in a time-sensitive environment. Campaign planning embodies both deliberate and crisis action planning. Both planning methods currently use a strategy-to-task approach to planning and execution in order to achieve the desired objective(s).



### **Joint Publication 5-00.1, *Joint Doctrine for Campaign Planning*, 25 January 2002**

This publication describes in greater depth the current strategy-to-task approach used in campaign planning. Adversary centers of gravity characteristics, critical capabilities, critical requirements, and critical vulnerabilities are defined and discussed extensively. Chapter 2 states, “The importance of identifying the proper COGs cannot be overstated.”

The term “decisive point” is defined as; “A geographic place, specific key event, critical system or function that allows commanders to gain a marked advantage over an adversary and greatly influence the outcome of an attack. In other words, a decisive point is the key to neutralizing or destroying an adversary COG.

### **Joint Publication 3-0, *Doctrine for Joint Operations*, 10 September 2001**

Joint Publication 3-0 discusses the fundamental principles of joint operations, planning guidance, and considerations for the conduct of joint operations. The term “End State” is defined as “the set of required conditions that achieve the strategic objectives.” This publication is complementary to JP 5-00.1.

### **USPACOM Joint Interagency Coordination Group/Counterterrorism**

The USPACOM JIACG/CT currently uses the JP 5-0, 5-00.1, and 3-0 approach to deliberate planning and center of gravity analysis. Additionally, a systems approach has been used to accomplish mission analysis of terrorist organizations. This systems approach is used to facilitate COG development and analysis for specific terrorist organizations, but then returned to the more conventional COG methodology when applied to deliberate planning.

### **USCENTCOM, OEF**

A classic strategy-to-task planning and assessment methodology was employed by USCENTCOM during Operation ENDURING FREEDOM. (Denhard 2004, 8). Planning

followed conventional Joint Publication approach while a weighted average algorithm was applied to assess component, operational and campaign objectives.

## **USCENTCOM, OIF**

When planning for Operation IRAQI FREEDOM, USCENTCOM utilized a hybrid approach combining the traditional strategy-to-task methods currently in joint doctrine with newer effects-based methods. Specifically, desired results were linked to each operational objective. From an air component perspective, desired effects were linked to tactical tasks.

Whereas joint doctrine provides the basis for all US doctrine, Air Force doctrine provides guidance for the application of air and space power. Additionally, Air Force doctrine complements joint doctrine. To that end, none of the documents contradicts the strategy-to-task approach used in joint doctrine.

**Air Force Doctrine Document 1 (17 November 2003)**

**Air Force Doctrine Document 2 (17 February 2000)**

**Air Force Doctrine document 2-1 (22 January 2000)**

AFDD 2-1 illustrates the process for developing a Joint Air Operations Plan. AFDD 2-1 defines “Effects” as “operational or strategic-level outcomes that functions are intended to produce.” In this context, “functions” refers to the functions of aerospace power. The example given is; a commander employs the function of counterair to achieve the effect of aerospace superiority. The various AF doctrine documents that discuss the functions of aerospace power address the concept of an effects-based approach in more detail; however, AFDD 2-1, Chapter 2 (Air Warfare Planning) does not.

Thus, the current Air Force approach is a hybrid based on the doctrinal definition of effects in AFDD 2-1. The functions of aerospace power are applied to achieve an “effect”. In this case, the effect is a specified or implied task produced by the strategy-to-task approach used

to develop the joint air operations plan. Indeed, Air Force doctrine has begun the transformation from an objectives-based methodology to and effects-based methodology.

### **The Transformation – An Overview of Effects-Based Operations**

The term “EBO” has been used to such an extent that it is difficult to nail down a single definition. One could argue that a single definition may be counter-productive however, for the purposes of unity of effort within joint doctrine, a single definition is necessary. Various definitions of EBO include:

*CADRE Thinking Effects, Effects-based Methodology for Joint Operations, Oct 2002:*

- Actions taken against enemy systems designed to achieve specific effects that contribute directly to desired military and political outcomes

*Smith, Effects-Based Operations, Nov 2002*

- Coordinated set of actions directed at shaping the behavior of friends, neutrals, and foes in peace, crisis, and war

*ACC/XP briefing, Jan 2004:*

- Operations which impose force against enemy systems to achieve specific effects that contribute directly to the military and political objectives

*JFCOM TEBO CONOPS, Jan 2004*

- Operations that influence and/or change the state of the Political, Military, Economic, Social, Infrastructure, and Information (PMESII) systems within the operational environment to achieve directed policy aims using the integrated application of selected instruments of national power

*Joint Warfighting Center, Joint Doctrine Series, Pamphlet 7, Operational Implications of Effects-Based Operations, 17 November 2004*

- Operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims

Besides the basic definition of EBO, there are many challenges that remain. Two of these are the connection between strategic objectives and tactical actions and the development of a parallel (or “Blue”) structure in the same manner friendly COGs are currently developed. Perhaps the first actionable article in the field of EBO is the CADRE paper *Thinking Effects, Effects-based Methodology for Joint Operations*.

***Thinking Effects, Effects-based Methodology for Joint Operations, Mann, Endersby, and Searle, CADRE, October 2002***

This CADRE paper presents a “theory grounded in effects-based thinking, a process to facilitate development of an organizational culture of EBO, and a lexicon that promotes a common language.”

The EBO methodology is described as an evolution of the current objectives-based methodology. EBO is a method to plan, execute, and assess operations to attain national security outcomes. The current objectives-based, strategy-to-task approach is moved forward through EBO by enabling commanders to examine the causal linkages whereby actions lead to objectives (or outcomes). This evolution is illustrated by comparing figures 1 and 2 below (Mann et al 2002, 47, 49).

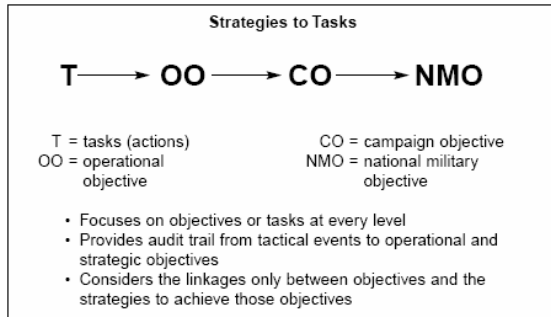


Figure 1. Objectives-Based Methodology (Mann et al 2002, 47)

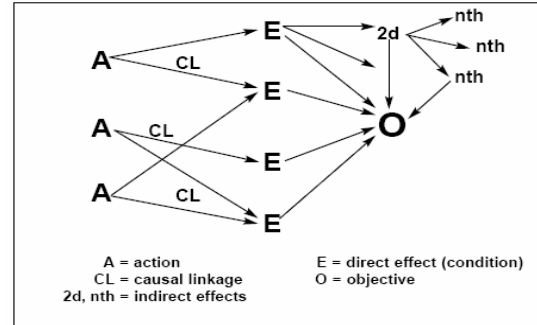


Figure 2. Effects-Based Methodology (Mann et al 2002, 49)

The authors state the most critical element of the EBO methodology is the concept of causal linkages; or why planners believe a given action will produce the desired effect. Further, by incorporating all four elements of national power as well as both lethal and non-lethal military means, EBO is broader in scope than the current objectives-based method. The term “effect” is defined as consisting of “a full range of outcomes, events, or consequences that result from a specific action.”

A direct effect is the outcome of a given action without any other influences between action and outcome. An indirect effect is the outcome of a given action with additional influences applied to the system between action and outcome. Indirect effects are also described as second or third order effects. A cumulative effect is the aggregation of a single or series of direct and/or indirect effects while a cascading effect is the operational or tactical result of an indirect effect that occurs at the strategic level.

To support this transformation in planning and assessment methods, efforts are underway to develop and field software to assist planners. Of note are efforts sponsored by the Air force Research Lab (AFRL) and the Australian Command and Control Information Sciences Laboratory.

## AFRL and Australian Modeling Efforts

As part of the ongoing effort to develop planning methods and tools for EBO, AFRL and the Australian Command and Control Information Sciences Laboratory have developed computerized tools for use by planners. While neither tool is ready for actual operations, both tools attempt to model the causal linkages between a given action and a desired outcome. The Australian work specifically describes a focus on developing a decision-making tool whereas the AFRL effort is focused on producing a strategy given a set of inputs. While the technical details of these methods will be discussed later, for now we simply note the approach used by White, et al. 2003 to overlay blue actions, effects, and objectives onto red centers of gravity (figure 3).

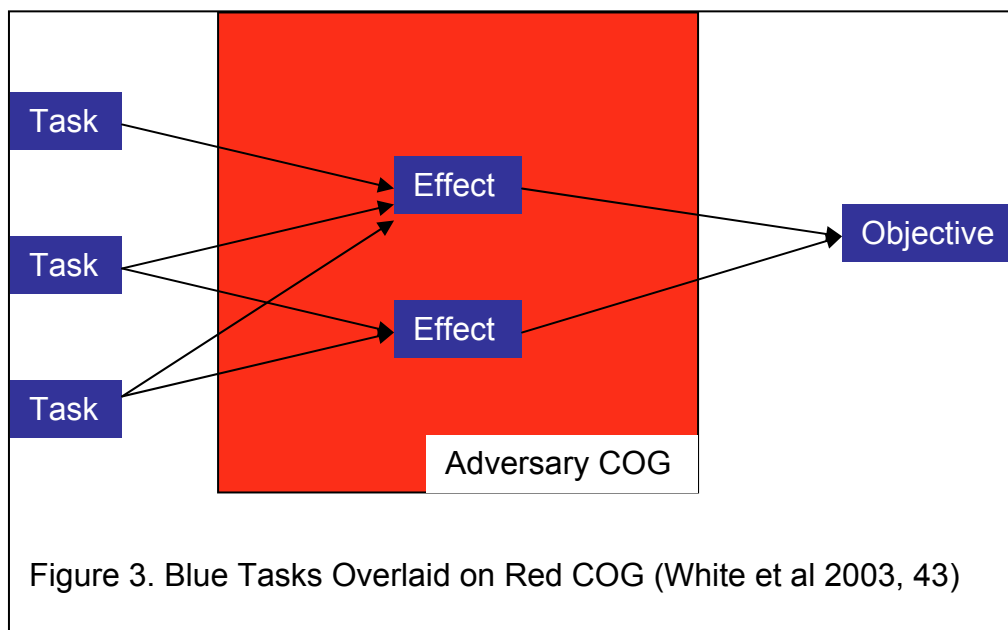


Figure 3. Blue Tasks Overlaid on Red COG (White et al 2003, 43)

The importance of the causal linkage between a given action or task and the desired effect(s) is clear but how can this understanding be gained by planners, and more importantly, by decision makers? While not a current military planning method, the concept of describing an adversary

through a systems dynamics approach is an initial step to understanding the causal linkages between an action and a desired outcome.

### **Modeling a Strategy for the War on Terrorism, Henderson, USAWC, 9 April 2002**

Dr. Henderson presents a strategy for conducting the war on terrorism in terms of a system and describes how the strategy must be adjusted over time. Two systems for modeling terrorism are presented in the article. The first is based on Warden's model for airpower while the second is based on systems dynamics. The Warden model is described as effective for conceptualizing the terrorist network in terms of its centers of gravity, but ineffective in describing the causal relationships between various components of the terrorist network. In that sense, the Warden model would not be an effective tool for EBO.

The systems dynamics model defines causal relationships between components of the terrorist network (or terrorist system) as well as relationships between terrorist networks and nation-states. This approach enables leaders to examine the effects of attacking components of the terrorist network in sequence or in parallel. The approach can also examine the effects (direct or indirect) upon a nation-state due to an attack on a terrorist network or vice-versa.

The systems dynamics method has one feature none of the other methods reviewed earlier have, feedback. The use of feedback provides insight into which components of the terrorist network are the most frequently utilized or the most critical. This is different than the concept of assessment used in current planning or the current EBO methodology. Assessment is presently an after-the-fact activity designed to determine if an action produced the desired outcome. The use of feedback as proposed by Dr. Henderson can provide insight into selecting an action in the first place. Thus, a systems dynamics approach to modeling terrorist networks can act as both a decision making tool and a decision assessment tool.

The Joint Warfighting Center has expanded the use of systems dynamics beyond a single organization to a system of systems approach. This methodology is described in Joint Doctrine Series Pamphlet 7.

**Joint Warfighting Center, Joint Doctrine Series, Pamphlet 7, *Operational Implications of Effects-Based Operations*, 17 November 2004**

This document represents the most recent thinking on EBO by US Joint Forces Command. The pamphlet defines EBO, discusses in detail an effects-based approach to planning, execution and assessment, and reviews operational implications to doctrine, leadership and education, and training among others.

The definition of EBO is “operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims.” Additionally, the following definitions are given as a baseline:

*Effect: The physical and/or behavioral state of a Political, Military, Economic, Social, Infrastructure, and Information (PMESII) system that results from a military or nonmilitary action or set of actions.* This is the first definition of an effect in the EBO context that refers to a “state” rather than an outcome or objective. Reference to a state implies the recognition that an adversary will move from one state to another during a conflict. Other definitions include:



- The **operational environment** is a composite of the elements, conditions, and influences that affect the employment of resources and capabilities and that bear on the decisions of the unit commander.
- A **system** is a functionally, physically, and/or behaviorally related group of elements that interact together as a whole. To facilitate a system-of-systems analysis, EBO currently considers that the operational environment is comprised of **political, military, economic, social, infrastructure, and information (PMESII)** systems. Analysis of these systems and their interrelationships provides the “holistic understanding” mentioned in the definition.
- The **integrated application** is the harmonized operation that results from an adaptable effects-based planning, execution, and assessment process.
- **Instruments of power** include all ways and means—diplomatic, informational, military, economic, and others—available to the President to influence the operational environment.
- **Directed policy aims** are the President’s objectives that comprise the desired national end state relevant to the operation at hand.

Section 2 describes an effects-based approach based on a “holistic understanding of the environment.” Improvements to current campaign planning methods by using an EBO methodology are described as:

- Linking of operational objectives to tactical-level actions through a specified set of effects.
- Systemic situational awareness and understanding of the adversary and operational environment enabled by a system-of-systems analysis (SoSA).
- Synchronization of “ends, ways, and means” using a harmonized application of the instruments of national power.
- Command and staff interaction across multiple echelons enabled by significant collaboration capabilities.
- Enhanced unity of effort between joint, multinational, and interagency organizations.
- A more accurate, rigorous assessment of the attainment of campaign objectives focused on system behavior rather than discrete task accomplishment.

The three EBO components (planning, execution, and assessment) are enabled by a collaborative information environment and operational net assessment. Operational net assessment provides the holistic understanding of the environment through a system of systems analysis or SoSA (figure 4). Within each of the six interrelated PMESII systems, nodes represent a functional component of the system (person, place). The links represent the relationships between the nodes (behavioral, physical, or functional).

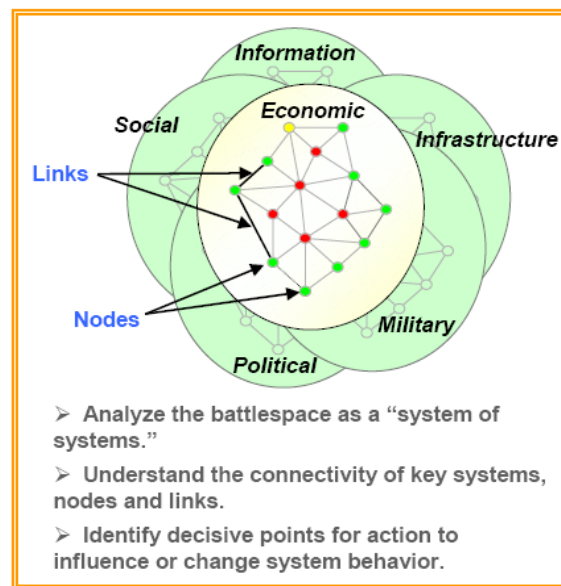


Figure 4. Systems of Systems Model (JWC Pam 7 2004)

Notably, the SoSA approach does not use the term “center of gravity.” The intent of SoSA is to produce a nodal analysis that forms the basis for coupling nodes to effects, actions and resources.

The effects-based planning section describes the development of a linkage between effects – node – actions – resources or ENAR (figure 5). The SoSA output determines the direct and indirect linkages across the PMESII. Understanding these relationships enables the JFC to select from a set of ENAR options when developing and selecting courses of action. In figure 5, direct relationships exist between adjacent nodes (nodes A and D and nodes D and C). Indirect

The diagram illustrates a network structure with nodes and links. The nodes are represented by circles containing labels:  $N_B$ ,  $N_A$ ,  $N_D$ ,  $N_C$ , and  $N_E$ . The links are represented by lines connecting the nodes. A link connects  $N_B$  to  $N_A$ , and another link connects  $N_A$  to  $N_D$ . A third link connects  $N_C$  to  $N_D$ , and a fourth link connects  $N_C$  to  $N_E$ . The links are labeled "Link".

es are given for the development of measures of effectiveness and

Overall, JWFC Doctrine Pam 7 and the CADRE *Thinking Effects* paper represent the most actionable and complete EBO descriptions and methodologies to date.

## Summary

Strategy-to-task is an objectives-based planning method currently used by the US Armed Forces. The methodology is effective for both deliberate and crisis action planning, well understood by the user and ties tactical actions to NCA objectives.

Joint publication 5-0 addresses in broad terms planning for the employment of military forces to attain strategic and operational level objectives. The vehicle for this is the Joint Operation Planning and Execution System. JP 5-00.1 describes in greater depth the current strategy-to-task approach used in campaign planning while JP 3-0 discusses the fundamental principles of joint operations, planning guidance, and considerations for the conduct of joint operations. The current 3-0 volume ties joint doctrine together with, national security strategy, and national military strategy.

Both USPACOM and USCENTCOM have used elements of an effects-based approach in recent efforts. PACOM has used a systems approach to accomplish COG development and mission analysis of terrorist organizations. When planning for Operation IRAQI FREEDOM, USCENTCOM applied a hybrid approach by linking results to operational objectives.

There are various definitions of EBO available. The most recent being from JWFC Doctrine Pamphlet 7 which defines EBO as; “operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims.” The current AFDD 2-1 definition of “effects” as “operational or strategic-level outcomes that functions are intended to produce” is consistent with this definition in that a “function of aerospace power” is simply a selected

instrument of national power. The AFDD 2-1 definition is a subset of the broader definition in Pamphlet 7.

EBO is a method to plan, execute, and assess operations to attain a desired national security end state. The methodology has evolved from a simplistic strategy-to-task, direct vs. indirect attack on enemy COGs to a system of systems analysis (SoSA) of the adversary's political, military, economic, social, infrastructure, and information systems to gain a holistic understanding of the adversary (see figures 1-6 below).

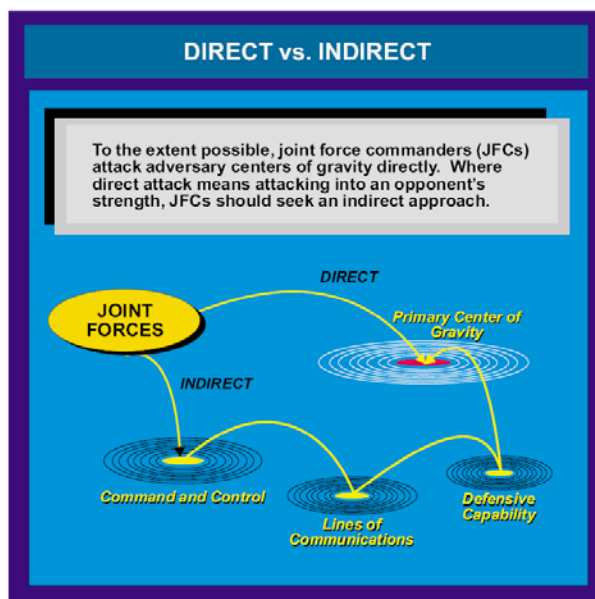


Figure 6. JP 5-0 Figure II-3 Direct vs. Indirect

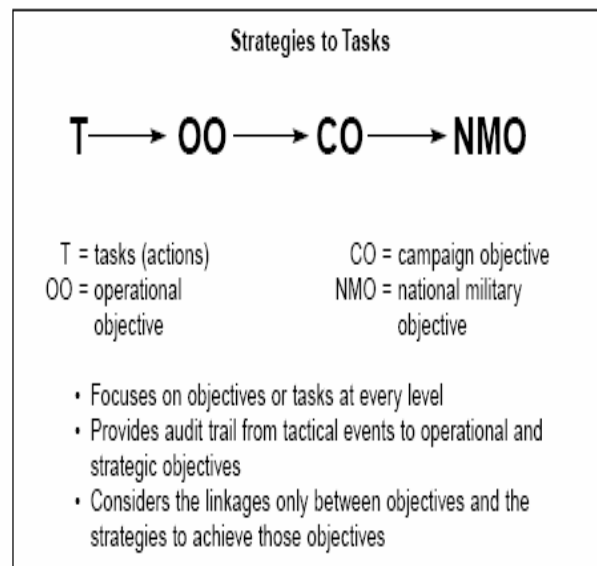


Figure 1. Objectives-Based Methodology (Mann et al 2002, 47)

Figures 1 and 6 represent the current planning and execution methods recommended in doctrine. Beginning in 2002 with Mann, Endersby and Searle the formulation began to address the linkages between actions, effects and objectives. Overlaid on an adversary COG in the process of modeling by White et al in 2003, the formulation began to represent the relationships between red and blue “systems” (figures 2 and 3 below).

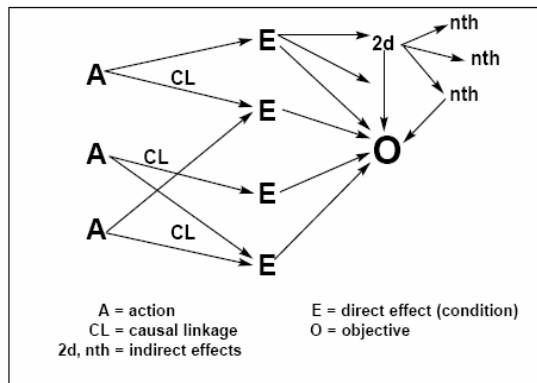
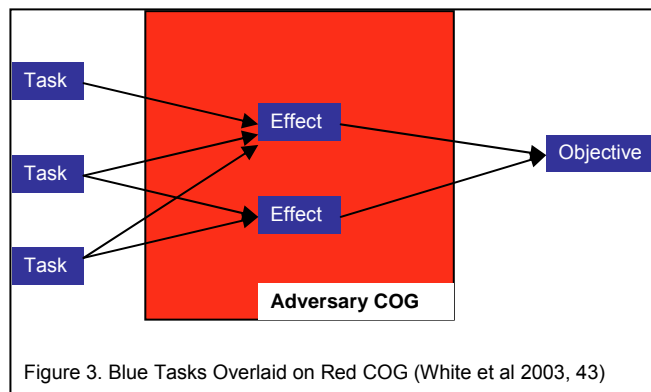


Figure 2. Effects-Based Methodology (Mann et al 2002, 49)



With the publication of JWC Pam 7 in 2004, the formulation moves fully to a system of systems baseline to develop the relationships between effects, nodes, and actions (figures 4 and 5).

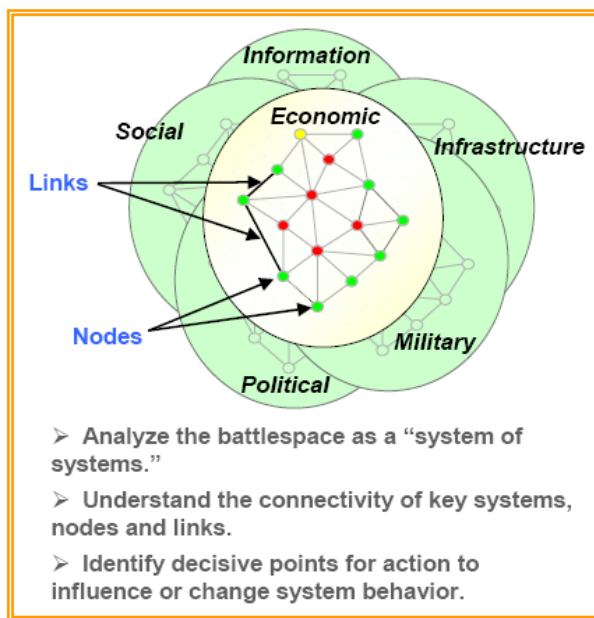


Figure 4. Systems of Systems Model (JWC Pam 7 2004)

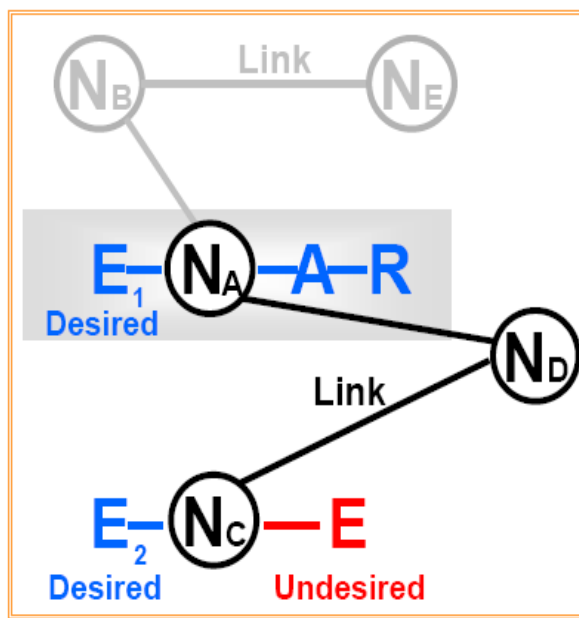


Figure 5. ENAR Within a PMESII System (JWC Pam 7 2004)

The EBO definition currently considers each PMESII element a system. This SoSA approach does not employ the traditional center of gravity analysis in joint doctrine. Effects-based planning utilizes the results of the SoSA for the development of a linkage between effects – node – actions – resources or ENAR (figure 5). The ENAR formulation is similar to that described in figure 3 but with three additions. First, resources are coupled to actions. Second, while blue actions and effects are overlaid on an adversary COG in figure 3, blue actions and effects are

overlaid on an adversary PMESII system in figure 4. This is a significant departure from the hierarchal methods in the strategy-to-task approach of current Joint Doctrine.

While SoSA addresses the most critical element of EBO (casual linkages between actions and effects) and will almost certainly provide greater insight into adversary strengths and weaknesses, it is not clear if the proposed ENAR linkage will be able to aggregate a series of irrevocable commitments of resources, or a series of decisions, into the desired national end state. Additionally, except for the AFRL computer model, none of the formulations discussed above are dynamic. In other words, once actions are taken the system must be re-evaluated to develop the next set of linkages. Finally, none of the formulations incorporate the use of feedback loops from systems dynamics.

To be fully effective EBO will need to accomplish five general functions. First, tie actions to the desired national end state. Second, provide insight into the causal linkages between adversary system components. Third, be dynamic enough to allow for changes in both friendly and adversary states. Fourth, provide a feedback mechanism to enable decision-making insight into the selection and assessment of actions involving the instruments of national power. Fifth, be easy to understand and use. The same method will need to be effective regardless of whether 18 months or 18 hours are available for planning.

The proposed methodology in JWFC Doctrine Pamphlet 7 is an excellent baseline in that the second and third functions are enabled through the effects-based processes described in the pamphlet. A multi-discipline approach similar to the risk modeling, assessment, and management methods proposed by Haimes (2004) would improve the EBO methodology and fully realize the first, fourth, and fifth functions.

## **APPENDIX B**

### **LITERATURE REVIEW OF OPERATIONS RESEARCH NETWORKS FOR MODELING TERRORIST ORGANIZATIONS**

**March 2005**



## **Summary**

To support planning, execution and assessment of military operations in the War on Terror a variety of methods are available for modeling terrorist organizations. Various methods from the fields of operations research, risk assessment and management, systems dynamics, complexity theory, and game theory are described below and summarized in table 1.

Models that support operations must have two fundamental properties. First, the model must be able to describe and represent the problem at hand. Second, the model must discriminate between alternatives (solutions to the problem) through sensitivity analysis. Whatever model is used, it is simply an aid to operations. To aid operations, the model must provide information to improve understanding of the problem and the potential alternatives, in short, the model must aid decision-making.

A decision making aid is not the same as a decision making tool that produces the strategy when the computer operator presses the enter button. Since a tool cannot completely model the complex, dynamic environment of modern conflict, the tool that produces a single strategy will always be wrong. Instead, the model (or models) should aid planning staff, operators, and ultimately the decision maker in understanding the problem, structuring the decision(s), and making the decision. Additional beneficial properties are a predictive capability, feedback, and a temporal element.

A predictive capability enables the decision maker to evaluate the potential consequences of a given action or to develop actions necessary to achieve a desired result. Further, the ability to accomplish sensitivity analysis through multiple repetition aids in the determination of priorities and required resources. However, even with the right priorities and resources defined,

a set of actions will still fail if the resources are in fact not available. This is where feedback in the model is very important.

Feedback within a planning model can help ensure resources are available to carry out a selected action. Indeed, with resources a part of the decision criteria feedback can help ensure only a feasible option is selected. Feedback within an adversary model is much more difficult and in a static model virtually impossible. A temporal element to the model can assist both in feedback within an adversary model and in making sequential decisions.

A temporal element or the ability for the model to represent changes in the system over time is critical to sustained operations. Once an initial decision has been made, further decisions will be needed, often among higher degrees of uncertainty. The model must be able to represent today's problem, not just yesterday's.

| Method               | Bayesian Network                      | Dynamic Bayesian               | Social Network<br>(with Max Flow) | Influence Net/Diagram       |
|----------------------|---------------------------------------|--------------------------------|-----------------------------------|-----------------------------|
| Field                | Ops Res.                              | Ops Res.                       | Ops Res.                          | Ops Res.                    |
| Representation       | Network                               | Network                        | Network                           | Network                     |
| Sensitivity Analysis | ♦                                     | ♦                              | ♦                                 | ♦                           |
| Predictive           | ♦                                     | ♦                              | ♦                                 | ♦                           |
| Feedback             |                                       |                                |                                   |                             |
| Temporal             |                                       | ♦                              |                                   |                             |
| Method               | Colored-Petri Net                     | Event/Fault Trees              | Dark Network                      | System Dynamics             |
| Field                | Ops Res.                              | Risk Mgmt                      | General networks                  | System Dynamics             |
| Representation       | Network                               | Event/Fault Tree               | Network                           | System of Systems (network) |
| Sensitivity Analysis | When combined with Influence Net      | ♦                              |                                   | ♦                           |
| Predictive           | When combined with Influence Net      | ♦                              |                                   | ♦                           |
| Feedback             |                                       |                                |                                   | ♦                           |
| Temporal             | When combined with Influence Net      |                                |                                   | ♦                           |
| Method               | Game Theory                           | AHP/ANP                        | Complexity                        | Risk Analysis               |
| Field                | Game Theory                           | Multi-Criteria Decision Making | Complexity                        | Risk Analysis & Management  |
| Representation       | Game Forms                            | Network - (ANP)                | Network                           | Multiple forms              |
| Sensitivity Analysis | ♦                                     | ♦                              |                                   | ♦                           |
| Predictive           | ♦                                     |                                |                                   | ♦                           |
| Feedback             |                                       | ♦                              | ♦                                 |                             |
| Temporal             | When combined with Influence diagrams |                                |                                   | Some methods                |

**TABLE 1: Summary of Modeling Methods**

## **Operations Research Methods**

### **Bayesian Networks**

A Bayesian network models a given system, or domain, that contains uncertainty due to lack of information to define the system connectivity or to randomness within the system. A Bayesian network can be developed with qualitative knowledge of system connectivity and estimates of probabilities from subject matter experts. Bayesian modeling is accomplished through conditional probabilities, i.e. the probability of A given B, and is Markovian by convention.

*Faizen and Priest, 2004*

Faizen and Priest use Bayesian networks to represent the causal structure within a center of gravity (COG). The representation is useful, according to the authors, for three reasons: 1) the combined states of the low-level requirements allow estimation of the state of higher level capabilities; 2) relationship among requirements and capabilities is uncertain and better modeled through probability; 3) the conditional independence property in Bayesian networks enables reasoning about these probabilistic strengths in a context dependent way. The authors use HUGIN, a software tool for building Bayesian networks, as the Bayesian engine for their analysis tool.

The methodology employed by Faizen and Priest provides an effects-based analysis capability. Additionally, commercial software is readily available and Bayesian networks are well understood. Two drawbacks to the author's method are the time required for construction and population of the COG network and the possibility of inconsistent models due to the complexity of the COG network.

*Kjaerulff, 1995*

Kjaerulff's *dHugin: A Computational System for Dynamic Time-Sliced Bayesian Networks* is the foundational work on Dynamic Bayesian networks. A dynamic Bayesian network represents a dynamic system using multiple instances or time-slices of a static network. As time passes, a new time-slice is added to the model and the old time slice is cut off.

*Caroli et al, 2004 and White et al, 2003*

Caroli et al and White et al describe the implementation of a dynamic Bayesian network in a "causal analysis tool" to either capture the critical vulnerabilities within a COG network (White et al, 2003) or accomplish course of action analysis (Caroli et al, 2004). As such, friendly actions are modeled against an adversary system in an effort to predict an effect (outcome). The authors also describe a wargaming tool that has potential use in sensitivity analysis.

Caroli et al identify a drawback to the causal analysis tool as "How certain can the strategist be that an action and causal link will lead to a desired effect?" While this is valid, a better question may be, "How certain can the strategist be that a link between an action and desired effect even exists and that it is modeled correctly?"

### **Influence Diagrams and Influence Nets**

An Influence Diagram captures the decision maker's current state of knowledge about the situation. Four types of nodes are used: decision nodes, chance nodes, consequence or calculation nodes and payoff nodes. Nodes are connected via directed arcs from a predecessor to a successor (Clemen and Reilly 2001, 52-53). An influence net is very similar.

Influence nets, a variant of Bayesian networks, are used to depict causal relationships between a given set of actions and events. Influence nets consist of nodes that represent

statements or beliefs and arcs that represent a directed, binary relationship between two nodes (Wagenhaults, 2002).

*Pate-Cornell and Guikema, 2002*

Pate-Cornell and Guikema combine probabilistic risk analysis, decision analysis and elements of game theory to describe an approach to setting priorities among countermeasures to terrorism. In this multi-disciplinary approach, the probabilistic model is represented in the form of an influence diagram. The authors introduce a two-sided influence diagram to represent adversary actions and friendly decisions in a single period. Since influence diagrams are snapshots at a given time, Pate-Cornell and Guikema employ elements of game theory to provide a dynamic element to their model. The model then becomes a series of two-sided influence diagrams based on the beliefs and decisions of both friendlies and adversaries. This is conceptually if not mathematically similar to the use of time-slices to add a dynamic element to Bayesian networks.

Building a top-level model of a given situation is relatively straight forward using this methodology. However, given the Bayesian nature of the probabilities in the influence diagram this method also suffers from the limitations of time required to build the detailed model and the possibility of inconsistent models, i.e. keeping the sequenced two-sided influence diagrams consistent.

*Wagnehaults, 2002 and Wentz and Wagenhaults, 2004*

The influence net used by Wentz and Wangehaults defines influence with two parameter values for each arc and a probability for each node in the net. From this information, a complete set of the conditional probabilities for each node in the network is defined. The authors state the influence net can then be used to assess the bearing of actions on the desired effects. Further,

sensitivity analysis is applied to assist in the selection of actions. To provide a temporal element to their methodology, Wagenhau's utilizes an algorithm that converts the influence net into a discrete event dynamic system. The mathematical formulation is a Colored-Petri Net.

### **Colored-Petri Nets**

*Wagenhau's, 2002 and Wentz and Wagenhau's, 2004*

The nodes in the influence net become transitions in the Colored-Petri net. Temporal information is provided as an input. The Petri net produces a timed sequence of probability changes given a set of events. The output is a probability profile of the change in likelihood of a given proposition as a function of time. In other words, a probability profile is a set of time windows. Once again, this is conceptually if not mathematically similar to the time-slices within dynamic Bayesian networks or sequenced two-sided influence diagrams.

Like other models, this methodology is also complex and time consuming. The authors state the current tools work well at the strategic and, to a lesser extent, the operational level but have limited value at the tactical level due to the pace of operations.

### **Social Networks**

*Renfro and Deckro, 2003*

The research by Renfro and Deckro merges elements of Operations Research with techniques from the Social Sciences. In social networks, interrelations and connections are represented in a network where the nodes are individuals or organizations and edges (directed or undirected) represent associations. The strength of an association is termed "social closeness".

Renfro and Deckro use a maximum flow mathematical program to analyze the social network. As with other models, the output is only as good as the input data. To compensate for uncertainty, sensitivity analysis can be readily accomplished.

## **Systems Dynamics**

*Henderson, 2002*

Henderson applies the concepts of systems dynamics from business to terrorism for the purpose of strategy development. Model boundary charts are used to define the problem and the components within the system. Components are defined as internal, external, or excluded. Casual loop diagrams are then used to relate the effect of the components on the system as a whole. Finally stock and flow diagrams track the accumulation of material, money, and information within the system.

The principle strength of this approach is that feedback is allowed whereas it is not in the operations research methods previously described.

## **Chaos and Complex Adaptive Systems**

*Chaos Theory: The Essentials for Military Applications, 1996*

This article is an excellent introduction to chaos that does not require a deep background in mathematics. Chaos theory describes a range of irregular behaviors in systems that are dynamic. James defines a system as a collection of elements along with a set of rules for how those elements change. The primary interest is in the motion and changes of the system. In general Chaotic systems

- Must have an underlying nonlinear process
- Use phase variables. Phase variables are time dependent properties that determine the system dynamics. The collection of all possible combinations of values for the phase variables is known as the phase space
- Have parameters that are constants in the system's equations of motion. Parameters represent a mechanism to control the amount of energy in a system



- Are sensitive to initial conditions (SIC). Any two initial states will follow trajectories that exponentially diverge from each other within the phase space

- A measure of how fast trajectories diverge is the Lyapunov exponent  $e^{kt}$  where  $k$  is a constant. If  $k$  is negative, small disturbances tend to get smaller indicating the system is not SIC. If  $k$  is positive, small disturbances grow exponentially with time indicating the system is SIC. One way of comparing two systems is by calculating an average Lyapunov exponent for the phase space of each system.

- SIC is a necessary but not sufficient condition for Chaos to occur

James states a Chaotic system MUST be: bounded, nonlinear, non-periodic, SIC, and mixing. What Chaos brings is the insight that a seemingly simple interaction can produce complicated dynamics.

Complexity theory is a science of interacting systems and explores the interaction and adaptation of systems. Further, complexity views organizations as complex adaptive systems.

*Marion and Uhl-Bien, 2002*

Marion and Uhl-Bien use propositions from complexity theory and complex leadership models to model leadership within Al-Qaeda. They coin the term “complex adaptive agent” to capture the idea that the difference between leader and follower is blurred within a complex adaptive system.

The dynamics within the complex adaptive system, or network, are represented by a series of causally linked events. The authors state complex dynamics exhibit multi-way chains of causality and often-conflicting feedback loops. In other words, events can change the network.

An important concept within complex adaptive systems is that of coupling.

Interdependencies within the system, or network, are described in terms of coupling strength.

Weak coupling allows innovation and adaptation to the environment but only provides a limited structure. Conversely, tightly coupled, or highly interdependent, systems offer structure but tend to stifle innovation. Complexity suggests that a mix of weak and tightly coupled systems predominate organizations. A terrorist network may be loosely coupled globally but tightly coupled locally. Hence, a global organization such as Al-Qaeda will be a highly adaptive and innovative organization.

A drawback of the complexity approach is that, as presented, it is qualitative. Since what is being modeled is the interaction among systems with varying degrees of coupling, this construct is very similar to that of a social network or influence network with varying probabilistic definitions of the nodes and edges. The positive side is that when information is limited a complexity approach may be more robust than an influence network or social network since feedback is allowed.

Other applicable references in the field of Chaos and Complexity include:

- Cambel, A.B. 1993. *Applied Chaos Theory, A Paradigm for Complexity*, San Diego CA, Academic Press Inc
- Banks, Steven C. *Tools and Techniques for developing Policies for Complex and Uncertain Systems*, RAND
- Bullock, Richard K., McIntyre, Gregory A. and Hill, Raymond R. 2000. Using Agent Based Modeling to Capture Airpower Strategic Effects. *Proceedings of the 2000 Winter Simulation Conference*. J.A. Jones, R.R. Barton, K. Kang, and P.A. Fishwick, editors. pp 1739-1746
- Sanchez, Susan M. and Lucas, Thomas W. 2002. Exploring the World of Agent Based Simulations: Simple Models, Complex Analyses. *Proceedings of the 2002 Winter Simulation Conference*. E. Yucesan, C.H. Chen, J.L. Snowdon and J.M. Charnes, editors. pp. 116-126

## **Dark Networks**

*Raab and Milward, 2003*

The authors introduce the concept of a dark network or an illegal, covert network. Examples given include drug cartels, terrorist networks and arms trafficking. Raab and Milward take a “network as problem” perspective to understand the relationship between adversarial networks. This is similar to using a social network with the nodes defined as organizations. The primary difference between a dark network and an overt network is the need for secrecy and the use of physical force. Hence, dark networks tend to take on a decentralized structure according to the authors.

This decentralized structure leads to a loose coupling among members of the network. Indeed, a number of “short” networks consisting of self-contained groups linked by function and need couple together to accomplish the goals of the parent organization.

Perhaps the most useful concept from this article is that of networks rather than hierarchal methods as an analysis tool to deal with the complexity involved with non-standard or asymmetric problems.

## **Game Theory**

*Pate-Cornell and Guikema, 2002* – see Influence Diagrams and Influence Nets above.

*Sandler and Acre, 2003*

The authors use game theory to model the interaction between terrorist groups and nation-states. They assume that each player will maximize a goal subject to a set of constraints. The authors state, “There is no true multi-period analysis of terrorist campaigns.” This is interesting in light of the efforts of Kjaerulff, Pate-Cornell and Guikema, and Wentz and Wagenhau to add a dynamic element to their modeling methods by using time snapshots.

## **Risk Assessment / Risk Management**

*Garrick et al, 2004*

Garrick et al demonstrate a method to assess the risks of terrorism, particularly attacks that have catastrophic consequences, quantitatively. The authors use event trees and fault trees to link threat and vulnerability assessment.

*Saaty, 1996*

Saaty illustrates the AHP in detail in his book *Decision Making with Dependence and Feedback, The Analytic Network Process* (1996). Saaty describes the AHP as an “a general theory of measurement used to derive ratio scales from both discrete and continuous paired comparisons in multilevel hierarchic structures.” The AHP has found wide application in multi-criteria decision-making, allows for both dependence and feedback, and can be used the physical and social domains. In a 1996 doctoral study of decision-making methods by Peniwati, the AHP fulfilled the 16 criteria under study better than all the other methods.

AHP subdivides a complex problem into levels arranged in ascending hierarchal order. At each level, components are compared relative to each other through pairwise comparisons. Levels are related to an adjacent upper level to integrate across the hierarchy. The result is a set of priorities and a method of scaling between actions or alternatives. The priority weights can assist with decisions among lower level options. The result of the AHP is a measure of relative importance between the alternatives, which can aid the decision maker. AHP can be extended to an Analytic Network Process to model dependencies and include feedback

*Haimes, 2004*

Haimes’ focus is based on the premise that a nation-state is a system of systems. Each system is further composed of some number of subsystems. The relationships among these

subsystems are stochastic, dynamic, nonlinear, spatially distributed, and hierarchical. To that end, Haimes' key result is; no single methodology (including the one he describes) can effectively handle the complexity and uncertainty involved. Instead, Haimes integrates several techniques.

To provide a holistic view of the model, hierarchical holographic modeling (HHM) is employed. The HHM result, combined with the risk filtering, ranking and management (RFRM) method ranks the elements of the model giving preference to those elements considered the most important (similar to ANP). Haimes states that in this application of HHM, the elements of the model would be "time-variant." Bayesian analysis is then applied to evaluate the sensitivity and specificity of intelligence information related to the system. Finally, a multiple objective decision tree is applied to select the action to be taken when the state of the system warrants it.

## BIBLIOGRAPHY

- Air Force Doctrine Document 1. *Air Force Basic Doctrine*. Washington: HQ USAF, 17 November 2003.
- Air Force Doctrine Document 2. *Organization and Employment of Aerospace Power*. Washington: HQ USAF, 17 February 2000.
- Air Force Doctrine Document 2-1. *Air Warfare*. Washington: HQ USAF, 22 January 2000.
- Banks, Steven C. *Tools and Techniques for developing Policies for Complex and Uncertain Systems*, RAND
- Bullock, Richard K., McIntyre, Gregory A. and Hill, Raymond R. 2000. Using Agent Based Modeling to Capture Airpower Strategic Effects. *Proceedings of the 2000 Winter Simulation Conference*. J.A. Jones, R.R. Barton, K. Kang, and P.A. Fishwick, editors. pp 1739-1746
- Cambel, A.B. 1993. *Applied Chaos Theory, A Paradigm for Complexity*, San Diego CA, Academic Press Inc
- Caroli Joseph, Fayette Daniel, Koziarz Nancy, and Stedman Terrance. 2004. Tools for Effects Based Course of Action Development and Assessment. 2004 Command and Control Research and Technical Symposium, San Diego, CA.
- Clemen Robert T. and Reilly Terence. 2001. *Making Hard Decisions with DecisionTools, second rev edition*. Pacific Grove: Brooks/Cole
- Denhard, David R. 2004. *Strategy-to-Task Overview*. Courseware, Department of Operational Sciences, Air Force Institute of Technology (AU). Wright-Patterson AFB OH.
- Denhard, David R. 2004. *Effects-based Operations Overview*. Courseware, Department of Operational Sciences, Air Force Institute of Technology. Wright-Patterson AFB OH.
- Falzon, Lucia and Priest, Jayson. 2004. *The Centre of Gravity Network Effects Tool: Probabilistic Modelling for Operational Planning*. DSTO Information Sciences Laboratory, Edinburgh South Australia.
- Garrick B. John, Hall James E., Kilger Max, McDonald John C., O'Toole Tara, Probst Peter S., Parker Elizabeth Rindskopf, Rosenthal Robert, Trivelpiece Alvin W., Van Arsdale Lee A., Zebroski Edwin L. 2004. Confronting the Risks of Terrorism: Making the Right Decisions. *Reliability Engineering and System Safety* V86: 129-176.
- Haimes Yacov Y. 2004. *Risk Modeling, Assessment and Management, second edition*. Hoboken: John Wiley and Sons, Inc.

- Henderson Darrall, 2002. *Modeling a Strategy for the War on Terrorism*. US Army War College. Carlisle Barracks, Pennsylvania.
- Joint Publication 1. *Joint Warfare of the Armed Forces of the United States*. 14 November 2000.
- Joint Publication 1-02. *Department of Defense Dictionary of Military and Associated Terms*. 12 April 2001 (as amended through 9 May 2005).
- Joint Publication 3-0. *Doctrine for Joint Operations*. 10 September 2001.
- Joint Publication 5-0. *Doctrine for Planning Joint Operations*. 13 April 1995.
- Joint Publication 5-00.1. *Joint Doctrine for Campaign Planning*. 25 January 2002.
- Joint Warfighting Center Joint Doctrine Series, Pamphlet 7. *Operational Implications of Effects-Based Operations*. US Joint Forces Command: 17 November 2004.
- Kjaerulff Uffe. 1995. dHugin: A Computational System for Dynamic Time-Sliced Bayesian Networks. *International Journal of Forecasting*: 89-111.
- Mann, Edward C., Endersby, Gary and Searle, Thomas R. 2002. *Thinking Effects, Effects-Based Methodology for Joint Operations*. College of Aerospace Doctrine, Research and Education Paper No. 15, Air University, Maxwell AFB AL.
- Marion Russ and Uhl-Bien Mary. 2002. Complexity theory and Al-Qaeda: Examining complex Leadership. *Presented at Managing the Complex IV: A Conference on Complex Systems and the Management of Organizations*, Fort Meyers FL.
- Marion Russ and Uhl-Bien Mary. 2002. Leadership in Complex Organizations. *The Leadership Quarterly* V12:389-418.
- Mateer Shawn M., 2002. *Influence Management a Tool for the War on Terrorism*. US Army War College. Carlisle Barracks, Pennsylvania.
- Pate-Cornell Elisabeth and Guikema Seth. 2002. Probabilistic Modeling of Terrorist threats: A Systems Analysis Approach to Setting Priorities Among Countermeasures. *Military Operations Research* V7 N4: 5-23.
- Peniwati, K.S. 1996. *The Possibility Theorem for Group Decision-Making: The Analytic Hierarchy Process*. Doctoral Dissertation. University of Pittsburgh, Pittsburgh PA
- Raab Jorg and Milward H. Brinton. 2003. Dark Networks as Problems. *Journal of Public Administration Research and Theory* V13 N4: 413-439.

- Reilly James, 2002. *A Strategic Level Center of Gravity Analysis on the Global War on Terrorism*. US Army War College. Carlisle Barracks, Pennsylvania.
- Renfro Robert S. and Deckro Richard F. 2003. A Flow Model Social Network Analysis of the Iranian Government. *Military Operations Research V8 N1*: 5-15.
- Saaty Thomas L. and Mu Enrique. 1997. The Peruvian Hostage Crisis of 1996-1997: what Should the Government Do? *Socio-Economic Planning Sciences V31 N3*: 165-172
- Saaty Thomas L. 1996. *Decision Making With Dependence and Feedback: The Analytic Network Process*. Pittsburgh: RWS Publications
- Sanchez, Susan M. and Lucas, Thomas W. 2002. Exploring the World of Agent Based Simulations: Simple Models, Complex Analyses. Proceedings of the 2002 Winter Simulation Conference. E. Yucesan, C.H. Chen, J.L. Snowdon and J.M. Charnes, editors. pp. 116-126
- Sandler Todd and Arce M. David G. 2003. Terrorism and Game Theory. *Simulation and Gaming V34 N3*: 319-337.
- Smith Edward. 2002. *Effects Based Operations: Applying Network Centric Warfare in Peace, Crisis, and War*. DoD Command and Control Research Program, Washington, D.C.
- Standing Joint Force Headquarters (Core Element). *Standard Operating Procedure and Tactics, Techniques and Procedures*. US Joint Forces Command: Draft 15 April 2004.
- Wagenhals Lee W. 2002. An Operational Concept for Effects Based Course-of-Action Development and Evaluation in a War Game. *Enabling Technologies for Simulation Science VI*, Sisti Alex F., Trevisani Dawn A., Editors, *Proceedings of SPIE Vol. 4716*, pages 251-262.
- Wentz Larry K. and Wagenhals Lee W. 2004. Effects Based Operations for Transnational Terrorist Organizations: Assessing Alternative Courses of Action to Mitigate Terrorist Threats. 2004 Command and Control Research and Technical Symposium, San Diego CA
- White Christopher M., Prendergast Michael, Pioch Nicholas, Jones Eric K. and Graham Stephen. 2003. Effects-Based Strategy Development Through Center of Gravity and Target System Analysis. *Enabling Technologies for Simulation Science VII*, Sisti Alex F., Trevisani Dawn A., Editors, *Proceedings of SPIE Vol. 5091*, page 36-46.



| REPORT DOCUMENTATION PAGE  |             |                           |                                  | Form Approved<br>OMB No. 074-0188                                     |   |
|--|-------------|---------------------------|----------------------------------|---|---|
| <p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p><b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b></p>  |             |                           |                                  |   |   |
| 1. REPORT DATE (DD-MM-YYYY)  |             | 2. REPORT TYPE            |                                  | 3. DATES COVERED (From – To)  |   |
| 01 – 06 - 2005   |             | Graduate Research Project |                                  | Jan 2005 – June 2005  |   |
| 4. TITLE AND SUBTITLE<br><br>EFFECTS-BASED DECISION MAKING IN THE WAR ON TERROR  |             |                           |                                  | 5a. CONTRACT NUMBER   |   |
|  |             |                           |                                  | 5b. GRANT NUMBER  |   |
|  |             |                           |                                  | 5c. PROGRAM ELEMENT NUMBER  |   |
| 6. AUTHOR(S)<br><br>Umstead, Robert K., Major, USAF  |             |                           |                                  | 5d. PROJECT NUMBER  |   |
|  |             |                           |                                  | 5e. TASK NUMBER   |   |
|  |             |                           |                                  | 5f. WORK UNIT NUMBER  |   |
| 7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)<br>Air Force Institute of Technology<br>Graduate School of Engineering and Management (AFIT/EN)<br>2950 Hobson Way, Building 640<br>WPAFB OH 45433-8865   |             |                           |                                  | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br><br>AFIT/GOS/ENS/05-15 |   |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>United States Pacific Command J3 / Joint Interagency<br>Coordination Group, Counter Terrorism Branch  |             |                           |                                  | 10. SPONSOR/MONITOR'S<br>ACRONYM(S)<br>USPACOM J3 / JIACG / CT        |   |
|  |             |                           |                                  | 11. SPONSOR/MONITOR'S REPORT<br>NUMBER(S)                             |   |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><br>APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.  |             |                           |                                  |   |   |
| 13. SUPPLEMENTARY NOTES  |             |                           |                                  |   |   |
| 14. ABSTRACT<br><p>In recent years, effects-based planning, execution, and assessment has moved from doctrinal debate to operational implementation in the U.S. military. Although effects-based operations (EBO) implementation strategies vary among the combatant commands and services, each faces the difficult task of planning and assessing their operations. USPACOM, the sponsor of this research, faces these challenges on a daily basis as they fight the war on terror in their area of responsibility</p> <p>From an operations research (OR) prospective, EBO formulations resemble networks with structures ranging from hierarchical (objective-effect-action-resource chains) to closed (systems-of-systems nodal chains). Many traditional OR network techniques can be employed to analysis these formulations. This project investigates two such techniques, network flows and risk analysis to identify nodes of influence (centers of gravity) and courses of actions (sets of actions). Applications of these techniques span the entire spectrum of military operations, but are particularly suited to the war on terrorism.</p> |             |                           |                                  |   |   |
| 15. SUBJECT TERMS<br>Centers of Gravity, Transnational Terrorism   |             |                           |                                  |   |   |
| 16. SECURITY CLASSIFICATION<br>OF:   |             |                           | 17. LIMITATION<br>OF<br>ABSTRACT | 18.<br>NUMBER<br>OF<br>PAGES  | 19a. NAME OF RESPONSIBLE PERSON   |
| a. REPORT  | b. ABSTRACT | c. THIS PAGE              |                                  |   | David R. Denhard, Lt Col, USAF  |
| U  | U           | U                         | UU                               | 73  | 19b. TELEPHONE NUMBER (Include area code)<br>(937) 255-6565, ext 3325<br>(emailname@afit.edu) |

Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std. Z39-18